SOME ASPECTS OF CONTROL OF THE SPOTTED ALFALFA APHID, <u>Therioaphis maculata</u> (Buckton)

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PREFACE

During recent years it has become increasingly obvious that control of the spotted alfalfa aphid under low temperature conditions needed study. Therefore, this area was chosen as a thesis problem. One obvious facet of this problem was the treatment of alfalfa seed with systemic insecticides, using different pelleting agents. These were evaluated for control of the spotted alfalfa aphid. Because adverse weather conditions caused very low aphid populations in the field during the winter, testing of contact insecticides at low temperatures was not as complete as was desirable. When aphid populations disappeared in the field, laboratory experiments were conducted using a colony of spotted alfalfa aphids established in a greenhouse. Laboratory experiments include treatment of alfalfa seed with systemic insecticides, a study of aphid damage to Buffalo and Cody varieties of alfalfa, and a study of aphid reproduction at various constant temperature levels.

Although some of the results presented in this paper are incomplete, they are enlightening in some respects and should point the way to more extensive research.

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INTRODUCTION

Following the discovery of the spotted alfalfa aphid in New Mexico in February 1954, this pest spread throughout the southwestern part of the United States and has caused a tremendous amount of damage to alfalfa. Damage and death of alfalfa plants are correlated with the number of aphids found feeding upon the plants. Nielson (1956) found that one aphid per plant, feeding and multiplying under uncontrolled conditions, caused death of alfalfa plants in 12 days. As would be expected, however, death or damage of plants depend upon factors in addition to the number of aphids present. Age and condition of plants, susceptibility of plants, environmental factors which affect aphid populations, and plant growth may be extremely important influences on plant mortality or damage.

Fecundity of these aphids is affected largely by temperature and humidity (Graham, 1959). Fecundity, in turn, affects the degree of plant damage and control of the aphids by insecticides. If temperature and humidity conditions are near optimum, aphid populations will increase rapidly, and badly damaged plants will likely result. These high populations also decrease the possibility of adequate control with insecticides. Although the per cent of initial aphid mortality from insecticide applications may be high, controls will not be lasting because of possible reinfestations from surrounding areas and from rapid build-ups from the surviving population.

Control of this pest at lower temperatures (below 60 degrees F.)

has been a major problem since its discovery. Many times during the winter months in Oklahoma, maximum temperatures range from 60 to 80 degrees F. This warm weather will cause a "false spring" in which alfalfa growth will increase, providing a lush feeding site upon which spotted alfalfa aphid populations may build up to economic levels. Then, at the time when insecticides should be applied for control of the pest, temperatures may drop below 60 degrees F. where they may remain for days or weeks. At these lower temperatures, all of our widely used aphicides are ineffective or only partially effective. Alfalfa stands are often badly thinned or destroyed completely as a result of poor low-temperature chemical control.

A possible remedy for low temperature chemical control of the spotted alfalfa aphid on seedling alfalfa plants lies in the application of systemic insecticides to the seed coat of alfalfa seed. However, many workers have found the treatment of alfalfa seed with systemic insecticides to be an ineffective means of control, probably because of the small amount of insecticide which is retained upon the seed coat. The use of sticking agents to pellet a greater amount of systemic material on to the seed should help alleviate the problem of availability of the insecticide for absorption by the plant.

This paper consists of four sections. Each section is handled independently of other sections because of the diversity of the particular topics. One section deals with damage studies, one section with reproduction studies, and two sections with chemical control, one of which concerns contact insecticides and the other dealing with systemic insecticides applied to alfalfa seed.

The purpose of the damage studies was to determine the number of aphids per plant upon which control recommendations should be made for any particular age of seedling plant. Plant damage caused by a known number of aphids feeding on a susceptible variety was compared to the damage of the same number of aphids feeding on a resistant variety.

In the reproduction study, reproduction, mortality, and theoretical aphid population levels were correlated with temperature. Results obtained were used in making recommendations for the timing of insecticide applications to insure adequate alfalfa protection. These results were also used as aids in the prediction of future population peaks, based upon temperature.

Four insecticide tests were conducted to evaluate the effectiveness of a number of contact insecticides as control agents at low temperatures. Results of low-temperature, small-plot tests were then compared to a moderate-temperature large-plot test. The use of an iso-paraffin oil as a diluent was also compared to water as an insecticide carrier in this section.

The last section concerns a comparison of control by treatment of alfalfa seed with systemic insecticides with control resulting from a variety of alfalfa resistant to the aphid. Various rates of two systemic materials, formulated on activated charcoal. were evaluated and compared to the same rates of both insecticides pelleted on to the seed. Hydroxyethyl cellulose and methyl cellulose were compared as sticking agents. Effect of high density aphid populations upon plants of a resistant variety and a susceptible variety from seed which had been treated with a systemic insecticide was studied. This test was conducted because of the poor results which were obtained from systemic seed treated plants when extremely high aphid populations attacked them at time of emergence.

REVIEW OF LITERATURE

The spotted alfalfa aphid, Therioaphis maculata (Buckton) was first reported as an alfalfa pest in the United States in February of 1954, causing damage to alfalfa in central and east central New Mexico (Dickson *et al.*, 1955). This aphid was probably introduced into central New Mexico in the summer or fall of 1953 and has spread rapidly over a large part of the United States (Dickson *et al.*, 1955). Smith (1959) described this insect as the most destructive and spectacular pest of alfalfa ever to enter California. He stated that it now occurs in most of the alfalfa-producing regions of the United States except the Pacific Northwest and the New England states.

The scientific nomenclature surrounding this insect has undergone several changes. Reynolds and Anderson (1955) referred to this aphid as *Therioaphis* (or *Myzocallis*) *trifolii* (Monell), soon after its discovery. Tuttle and Butler (1954) referred to it as the yellow clover aphid, *Therioaphis ononidis* (Kalt.), which has long been known as a minor pest of clover in central and eastern United States. However, Davis (1914) had reported that the yellow clover aphid would not survive on alfalfa. Dickson *et al.*, (1955) suggested that *Therioaphis maculata* (Buckton) is the spotted alfalfa aphid or the "yellow clover aphid on alfalfa", which was described as *Chaitophorus maculata* Buckton from India in 1899 from specimens taken on alfalfa near Jodhpur.

Although alfalfa (*Medicago sativa*) is the most important economic host of the spotted alfalfa aphid, other legumes also serve as hosts for the insect. Peters and Painter (1957) found a total of 23 species in the four genera Medicago, Melilotus, Trifolium, and Trigonella to be suitable hosts for the aphid.

Feeding of the spotted alfalfa aphid causes severe damage to the alfalfa plant. These insects prefer the lower surface of leaves but will feed on the entire plant (Harpaz, 1955). Harpaz found that spotted alfalfa aphids cannot withstand starvation for a long period of time. Forty per cent of the nymphs survived 16 hours without food, but none survived 22 hours without feeding. Diehl and Chatters (1956) stated that the insect inserts its stylets intercellularly and feeds within the phloem and mesophyll parenchyma. In their studies, greatest amounts of damage were evident within the mesophyll where the toxic substance or substances appear to cause lysis of the cytoplasm. These areas, they stated, may be visibly correlated with the macroscopic chlorotic areas of the leaves.

According to Paschke and Sylvester (1957), the initial damage symptoms were yellow vein-banding, followed by local chlorotic areas. In response to continued attack, leaves dropped, the plant was stunted in growth and showed wilting. Death of the plant soon followed. Peters and Painter (1958) found that feeding of the spotted alfalfa aphid induced a pathological "vein-clearing" senescence in leaves growing above those fed upon, as well as diffuse local yellowing near the feeding site. The damage was similar to virus damage of alfalfa plants described by Matthews (1951). However, Reynolds and Anderson (1955) suggested that damage is probably caused by a toxin secreted by the aphid.

One aphid per plant, feeding and multiplying under uncontrolled conditions, killed plants in approximately 12 days, according to Nielson (1958). Harpaz (1955) found that a single leaflet, the total area of which amounted to no more than 123 mm. /sic/ supported 99 aphids of all stages before it succumbed. If no more than one aphid per seven mm. were present, no changes in the leaf were noticed externally.

The highest number of young produced by a female aphid in one day was nine (Harpaz, 1958). Nielson and Barnes (1957) related that reproduction was greatest in the first 16 days after the last molt and was correlated with temperature. Dickson et al. (1955) found more nymphs produced per female at an average mean temperature of 79.1 degrees F. than at an average mean temperature of 67.4 degrees F. Nielson and Barnes (1957) reported that the average number of nymphs produced per day was three from alate females and four from apterous females. They pointed out that temperature, predators, and fungus diseases influenced the total aphid population in the field. According to Graham (1959), fecundity and duration of reproduction were greatly affected by temperature and humidity. He found that low humidity gave a longer reproductive period than two higher levels at all temperatures. He further stated that maximum fecundity was reached at 25 degrees C. at low and intermediate humidities and at 20 degrees C. at high humidity. Other factors may play an important role, however. Ball (1958) indicated that short daily exposures to the longer wavelengths of light resulted in the birth of fewer nymphs over a period of several months.

Thirty-seven days was the average life of the spotted alfalfa aphid in Harpaz's test (1955). He also found that growth and development varied with the month of the year (probably because of the difference in temperature). The most rapid development, in Harpaz's studies was in July when the cycle was completed in 10 days. Nielson and Barnes (1957) found the developmental period to be six days in August.

Control of the spotted alfalfa aphid has proved to be a problem since its discovery in 1954. Although predators do not always prevent outbreaks of the aphid, they are important in holding down light infestations and preventing reinfestations after a chemical control treatment has been applied (Smith and Hagen, 1956).

Alfalfa varieties, resistant to severe attacks of the spotted alfalfa aphid, have been successfully used as a control method for the insect. Stanford (1955) noted that Lahontan is a resistant variety, but it is not adapted to the growing conditions of the Southwest. He suggested that the level of aphid resistance present in Lahontan might be transferred to adapted varieties, the resulting new variety would do much to solve the aphid control problem. Harvey and Hackerott (1958) believed, however, that the factors responsible for resistance are not transferrable. Antibiosis and tolerance appeared to be the most important mechanisms of resistance (Howe and Smith, 1957).

Temperature may affect the amount of resistance in a particular variety, according to Hackerott and Harvey (1959). In their studies, aphid survival and reproduction were retarded more at high than at low temperatures. Resistant plants on which populations could not be maintained at 80 degrees F. supported limited populations at 60 degrees F.

Howe and Smith (1957) showed the value of aphid-resistant varieties. In their tests, the resistant variety, Lahontan, produced 289 per cent of the dry weight of African, 359 per cent of California Common 49, and 403 per cent of Caliverde. Dobson (1958) found Lahontan and New Mexico 16 to show only slight damage in the seedling stage. He stated that Ranger and African, semi-tolerant varieties, were injured by aphid attack but recovered so that, at the end of the first production-period they produced as much hay as the plots showing best control. Epley variety is also believed to be resistant to the spotted alfalfa aphid (Epley, 1957).

Howe and Smith (1957) noticed that Lahontan displayed only a small amount of honeydew, whereas varieties susceptible to the aphid were generously covered with the secretion. Maxwell and Painter (1959) found the rate of honeydew deposition to be influenced almost directly in proportion to the known amount of resistance found in the host plant. They suggested that possibility that the rate of honeydew deposition by aphids might be used to measure the degree of resistance of host plants to aphids.

Several workers showed that the spotted alfalfa aphid is very susceptible to most of the organic phosphate insecticides and to several chlorinated hydrocarbon insecticides. SYSTOX, META-SYSTOX, parathion, malathion, DIAZINON, American Cyanamid 12008, endrin, TEPP, and toxaphene gave excellent control, according to Reynolds and Anderson (1955). To this group of insecticides, Bieberdorf and Bryan (1956) added methyl parathion, CHLORTHION, and American Cyanamid 3911. Randolph (1957) suggested that BHC also gives adequate mortality.

As Bieberdorf and Bryan (1956) pointed out, the speed of action of chemicals for control of this insect is less important than the lasting qualities of the compounds, due to the constant reinfestation of alfalfa from untreated fields outside of the control area. In their tests, SYSTOX showed the greatest residual effect. Baker (1955) reported that SYSTOX was the only insecticide tested that gave control for more than five days. He noted that a toxaphene-DDT mix gave a longer protection period than the majority of the insecticides and combinations of insecticides tested.

The major difficulty in chemical control of the spotted alfalfa aphid is the ineffectiveness of chemicals at lower temperatures. A false spring, caused by days and weeks of mild or hot weather, brings out new growth to alfalfa and provides a feeding ground for aphids. This period is often followed by days or weeks of 20 to 30 degree F. temperatures. The proper time to apply insecticides would be during this period of low temperatures.

Most of the insecticides found to be effective against the spotted alfalfa aphid were more effective at higher temperatures. Hoffman (1956) believed this to be due largely to the fact that many of these insecticides act as fumigants, so that an increase in temperature caused an increase in volatility, which resulted in greater effectiveness of the compound. Cressman et al. (1953) found that kill on scales with parathion was faster at 90 degrees F. than at 60 degrees F.; however, at 60 degrees, mortality increased greatly before the 40-day count. Hoffman (1956) found parathion to be more toxic to house flies at 90 degrees F. than at 70 degrees F. He noted that control with malathion and toxaphene increased with an increase in temperature from 62 to 82 degrees F. Roan and Maeda (1953) found death caused by inhibition of cholinesterase enzyme in the oriental fruit fly to be the most rapid at 37 degrees C.

Although most insecticides are more efficient at these higher temperatures, DDT is more effective against many insects at lower temperatures (Andres et al., 1955). Guthrie (1950) found essentially the same results with the German cockroach; DDT, pyrethrum, and lindane were most toxic at 14.5 degrees C. and least toxic at 32 degrees C. Hofmaster and Greenwood (1953) found that SYSTOX gave better results on mites at 53 degrees F. than at 70 degrees F. He noted, however, that effectiveness of all insecticides were materially reduced at a very low temperature range of 25 to 28 degrees F.

Cook (1959) stated that a great deal of THIMET'S insecticidal properties were due to its action as a fumigant. In his tests with this material for control of the pea aphid, he found THIMET particularly valuable because it killed the aphids by fumigation at lower mean temperatures (44.7 and 49.1 degrees F.). Peebler (1957) suggested that methyl parathion would kill the spotted alfalfa aphid at lower temperatures. It is possible, he relates, that METACIDE, a mixture of methyl and ethyl paration may kill at temperatures lower than methyl parathion alone. He also reported phosdrin showing effective mortality at temperatures below 60 degrees F. Hofmaster and Greenwood (1953) stated that TEPP dust rendered better cold weather results than any other available insecticide used against mites on strawberries. Walton and Howell (1954), however, showed green peach and turnip aphid control with TEPP dust to be most affected by a drop in temperature, decreasing from 79 per cent control at 75 to 77 degrees F. to 58 per cent at 51 to

54 degrees F. In their tests, parathion dust exhibited a smaller reduction in control with a drop in temperature; it showed a decline in control of 87 per cent at 75 to 77 degrees F. to 72 per cent at 51 to 54 degrees F.

The failure of parathion to give long-lasting control of the spotted alfalfa aphid, despite satisfactory initial kill was believed to be due to the destruction of natural enemies, according to Bartlett (1958). He found that late larval and pupal stages of the internal parasites of the aphid were not all killed by relatively high dosages of the most toxic aphicides tested, but those materials having persistent residues destroyed the adults upon emergence.

Reynolds and Dickson (1955), van den Bosch _et al_. (1956), and Fenton (1959) found parathion to be the insecticide most severely toxic to natural control agents. Fenton (1959) found endrin least toxic to the entomophagus arthropods, whereas van den Bosch _et al_. (1956) reported that DDT is least harmful of those tested to beneficial insects commonly found in alfalfa fields.

Bartlett (1958) found that, with aphicides providing an LD-95 for the spotted alfalfa aphid, conservation of coccinellids was highest with nicotine sulfate, and decreased in degree with schradan, demeton, TRITHION, phosdrin, pyrethrum extract, TEPP, lindane, BHC, toxaphene, parathion, malathion, and rotenone. Demeton, because of its high aphid toxicity and favorable effect on coccinellids, parasites, and pollinating insects was suggested as the most practical material for integrated chemical and biological control of the spotted alfalfa aphid, according to Reynolds and Dickson (1955) and Bartlett (1958). Treatment with selective insecticides such as SYSTOX would, in general, by preserving natural enemies, have the effect of throwing the balance in favor of the natural enemies (Stern et al, 1959).

The use of systemic insecticides is another possibility for chemical control of the spotted alfalfa aphid. Many workers have suggested that systemics will give a three to five-week protection period for alfalfa plants after emergence, thus giving the plants an opportunity to gain growth which will make them more tolerant to aphid populations. Application of systemic materials, especially as a seed treatment, would circumvent vagaries of temperature fluctuations or adverse winds which limit the use of external applications. The use of systemics would also be less destructive to parasites and predators.

Reynolds et al. (1957) found that cotyledons of alfalfa contained the highest concentration of toxicant, and that toxicant is not translocated in substantial amounts to other plant parts. The toxicant, they reported, exists in plants in a concentration gradient ranging from the greatest value in the oldest leaves to the lowest value in the youngest leaves. Ten parts per million or less or demeton, THIMET, or DI-SYSTON was toxic to the spotted alfalfa aphid (Reynolds et al., 1957).

Temperature plays an important role in length of effectiveness of systemic insecticide. Roth (1959) found that treatment of alfalfa seed with systemics provided control of the aphid on seedlings for up to 10 weeks, depending on temperature. Metcalf et al. (1959) noted that rates of oxidation of DI-SYSTON metabolites were accelerated in cotton leaves by increased temperature between 37 and 100 degrees F. In their tests, the rate of oxidation of the sulfoxide metabolite increased about 1.9 times for each 10 degree C. rise in temperature.

Insecticidal activity in seed treated plants is directly related to the quantity of solution absorbed by the seed according to David and Gardiner (1955). They found that the same amount of demeton was more effective when absorbed by bean seeds through soaking than when watered on to the soil around the seed. Soaking of alfalfa seeds, however, resulted in a reduction of both germination and plant emergence (Bishop and Burkhardt, 1959). In order to keep more insecticide on the seed coat, Roth (1959) and Bishop and Burkhardt (1959) successfully used methyl cellulose to pellet systemic insecticides on alfalfa seed for control of the spotted alfalfa aphid.

Reynolds *et al.* (1957) found that treatment of alfalfa seed with THIMET on activated charcoal did not show satisfactory results. They suggested that there is very little difference in effectiveness with charcoal seed coating, with emulsion, or with granules in the seed row. Dobson and Watts (1957) reported that THIMET, as a seed treatment or as a granulated formulation is relatively ineffective in preventing spotted alfalfa aphid injury to seedling alfalfa. Dobson (1958) found Bayer 19639 (DI-SYSTON) granules, at one pound actual per acre, to be more effective than THIMET at the same rate during "explosive" and relatively static high points of infestations, but both materials were effective during waning periods of the population cycle. In his tests, DI-SYSTON at one pound actual per acre gave good control for 11 days and a partial control for some time thereafter.

Roth (1959), in his tests, showed control of the spotted alfalfa aphid for up to 10 weeks with DI-SYSTON pelleted on the seed with five per cent methyl cellulose. Using two per cent methyl cellulose as a sticker, Bishop and Burkhardt (1959) reported that DI-SYSTON at two and four pounds actual per 100 pounds of alfalfa seed, resulted in 100 per cent control of aphids for six weeks; one pound of DI-SYSTON gave 95 per cent control for the same period. In their tests, THIMET at four pounds actual showed 100 per cent control for four weeks, 85 per cent for the fifth week, and 75 per cent for the sixth week. They found no difference in control with any rate of DI-SYSTON or four pounds actual THIMET per hundred pounds of seed.

Systemic seed treatment often causes a phytotoxic effect in seedling plants. Bishop and Burkhardt (1959) reported that both germination and emergence of alfalfa were reduced after six months of storage of seeds soaked in demeton. Skoog (1959) stated that wheat stands were reduced by seed treatments but were not affected by systemics in granular formulations. Parencia et al. (1957), in 1954, found cotton emergence reduced by 39 per cent by American Cyanamid 12008, applied at one-half pound actual per acre. In their tests the following year, one pound actual per acre of American Cyanamid 3911 and 12008 did not affect germination. Gifford (1959) found adverse effects on germination with all rates of THIMET plus stickers made of oils of soybean, peanut, corn, or rice. In tests by Roth (1959), seed treatments with DI-SYSTON or THIMET, pelleted with methyl cellulose, did not affect germination in the field but caused a slight reduction of germination in the greenhouse. Adkisson (1958) noted that, when the soil was cool and damp, serious reduction in cotton stands were evident with seed treatments of THIMET and DI-SYSTON. When he added the fungicide nabam to the seed treatments, however, much better stands resulted.

Systemic materials also caused some change in the nutritive value of the plant (Hacskaylo, 1957). In Hacskaylo's tests, reducing sugars, sucrose, and starch accumulated in young plants treated with THIMET, but soluble protein nitrogen decreased. He noted that chloroform soluble and insoluble phosphorous increased with increasing levels of THIMET. Also, THIMET tended to cause an increase in the oil content of embryos at the expense of protein formation.

DAMAGE STUDIES

In order to determine the number of aphids that an alfalfa plant can tolerate before control agents should be applied, it is necessary to find the number of aphids required to cause severe damage or death of the plants in a specific period of time. In order to answer this question, plants were inoculated with varying quantities of aphids and carefully observed over a 10-day period. In addition, susceptibility to aphid attack and aphid damage were compared between plants of a susceptible variety and of a resistant variety.

Methods and Materials:

Approximately 20 alfalfa seeds of Buffalo and Cody (Sorensen, 1959) varieties were planted in six-inch flower pots. Upon emergence, plants were thinned to one plant per pot.

Plants of the susceptible variety, Buffalo, were inoculated with a known number of aphids immediately after emergence and at weekly intervals for four weeks thereafter. Cody alfalfa, a resistant variety, was inoculated with a known number of aphids upon emergence at one week after emergence. Glass tubes were placed over the alfalfa plants. These two-inch-diameter tubes were sterilized in a sodium dichromate solution[1] and rinsed in tap water. Over one end of each tube was placed

[1]Sodium dichromate dissolved in concentrated sulfuric acid.

a strip of nylon cloth, held in place by a rubber band to prevent escape of aphids from test plant.

Four quantities of aphids were used with each age plant. One, two, three, and four aphids per plant were introduced to both varieties upon emergence. One, two, three and ten aphids per plant were introduced on both varieties one week after emergence. At two weeks post emergence, one, two, ten and twenty aphids per plant were placed on Buffalo variety plants. One, ten, twenty, and thirty aphids were used on the same variety at three weeks post emergence. At four weeks after emergence of the Buffalo plants, one, ten, twenty-five, and forty aphids were introduced to each plant. Each quantity of aphids per plant was replicated five times.

Only adult aphids were used where 10 or fewer aphids were introduced per plant; however when 20 to 40 aphids were introduced per plant, both adult and nymphal aphids were used. The fact that one plant might have received a higher percentage of adult aphids than another plant may have caused some of the variation in damage of the plants when 20 or more aphids were involved.

When the plants reached the desired age, the desired quantity of aphids were placed on them. The glass tubes were then placed over the plants, and each was checked daily. When a plant was found not to be infested, it was reinfested with the same number of aphids which had been initially introduced on it. This procedure was used until 10 days after the initial introduction. Thereafter, plants were not reinfested when infestations disappeared.

Data were taken daily concerning the visible damage of plants, death of plants, and susceptibility of plants as exemplified by their ability to host or repel aphid infestations. Infestation data are recorded for only the emergence and one-week phases of the study in order to compare the susceptibility of Buffalo to the resistant variety, Cody. Plants two weeks or older seldom required reinfestation. These daily data were taken over a period of 10 days. Thereafter the same data were taken on occasions over a total period of 46 days.

Results:

A great deal of variation in damage and in time required for death of plants by aphid feeding was noted among the different replicates. This was probably due to such factors as individual plant resistance or susceptibility, maturity of the aphids, tolerance of the plant to aphid feeding, vigor of plant, etc. Regardless of the cause, these variances made it very difficult to make an accurate evaluation of the plants' reactions to any known quantity of aphids.

Many times, plants showed severe damage and looked nearly dead. When this point was reached, aphid populations became very light or disappeared completely. The plant, then, might go several days before it died or it might have eventually recovered from the damage. This phenonemon makes the figure for "days to death of plant" somewhat misleading.

Susceptible Variety at Emergence

Buffalo variety, when infested with aphids upon emergence from the soil, was killed by four aphids per plant in three to six days, as shown by the data from three of the five replicates (table 7).

The other two replicates, although they recovered from the damage, were showing severe damage at six days (table 1). Four aphids per plant, then, on newly emerged plants, would certainly warrant the initiation of control procedures.

Although one, two, or three aphids per plant did not cause plant mortality until after 13 days had elapsed (table 7), all showed severe damage within 10 days (table 1). Three aphids per plant caused severe damage in seven days. An infestation of three aphids per plant, shortly after seedling emergence, then, should also receive control measures.

Very few plants required reinfestation until the ninth day (table 5). At this time, plants were heavily damaged (table 1) and would not support a normal infestation. A total of 22 plants were reinfested during the initial 10 days, 16 of these during the last two days of the period (table 5).

Resistant Variety at Emergence

Cody variety plants required reinfestation throughout the initial 10-day period (table 5). A slightly larger number of plants required reinfestation during the last two days than during the first eight days of the period. This was probably due to the increase in effectiveness of the resistant qualities of the plant, rather than excessive damage, as was the case with the susceptible variety. A total of 41 Cody plants were reinfested during the period. This was approximately twice as many as required reinfestation in the case of the susceptible variety.

In addition to its ability to repel the aphids, supporting only approximately half as many aphids as Buffalo, Cody displayed a much

Table I. Comparison of plant damage of the aphid resistant Cody alfalfa and of the susceptible Buffalo alfalfa, caused by attacks of the spotted alfalfa aphid, <u>Therioaphis</u> <u>maculata</u> (Buckton) when aphids were introduced on plants at emergence from the soil. Stillwater, Oklahoma. 1959.

	Damage Ratings							
Days after infestation	Aphids Per Plant Cody Alfalfa				Aphids Per Plant Buffalo alfalfa			
	1	2	3	4	1	2	3	4
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	*	**
4	0	0	0	0	0	*	*	***
5	0	0	0	0	*	**	**	***
6	0	0	*	0	*	**	**	****
7	*	*	**	*	**	***	****	****
8	*	**	***	**	***	***	****	*****
9	*	*	****	*	***	***	****	*****
10	0	**	***	*	****	****	****	*****

0 - no visible damage
* - very light chlorosis of lower leaves and/or slight wilting of top leaves
** - light chlorosis of lower and top leaves (yellow-veining) and light wilting of leaves
*** - moderate chlorosis of leaves (general yellowing) and moderate degree of wilting, plant stunted (little growth)
**** - heavy chlorosis of leaves (yellow) and heavy wilting of plants (stems and leaves), no growth
***** - top leaves yellow, lower leaves necrotic, stems badly wilted, plant nearly dead

Table 2. Comparison of plant damage of the aphid resistant Cody alfalfa and of the susceptible Buffalo alfalfa, caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton) when aphids were introduced on plants at one week after emergence. Stillwater, Oklahoma. 1959.

	Damage Ratings							
Days after infestation	Aphids Per Plant Cody Alfalfa				Aphids Per Plant Buffalo Alfalfa			
	1	2	3	10	1	2	3	10
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	*	*	*	*	*	*	*
4	0	*	*	**	*	*	*	**
5	0	**	**	**	*	*	**	**
6	0	**	***	**	**	**	***	***
7	0	*	**	**	***	***	****	****
8	0	**	*	**	***	***	****	****
9	0	*	*	*	***	***	****	****
10	*	*	*	*	***	****	****	*****

0 - no visible damage
* - very light chlorosis of lower leaves and/or slight wilting of top leaves
** - light chlorosis of lower and top leaves (yellow-veining) and light wilting of leaves
*** - moderate chlorosis of leaves (general yellowing) and moderate degree of wilting, plant stunted (little growth)
**** - heavy chlorosis of leaves (yellow) and heavy wilting of plants (stems and leaves), no growth
***** - top leaves yellow, lower leaves necrotic, stems badly wilted, plant nearly dead

Table 3. Damage to Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when aphids were introduced on the plants at two and at three weeks after plant emergence. Stillwater, Oklahoma. 1959

	Damage Ratings							
Days after infestation	Two Weeks				Three Weeks			
	Aphids Per Plant				Aphids Per Plant			
	1	2	10	20	1	2	10	20
1	0	0	*	*	0	0	0	0
2	0	0	*	**	0	*	**	***
3	0	0	*	**	0	**	****	****
4	*	0	**	***	*	***	*****	****
5	*	*	**	***	**	***	*****	*****
6	***	***	****	****	***	****	*****	*****
7	***	***	****	****	***	*****	*****	*****
8	***	***	****	*****	***	*****	*****	*****
9	***	****	****	*****	***	*****	——	*****
10	****	****	*****	*****	****	*****	——	*****

0 - no visible damage
* - very light chlorosis of lower leaves and/or slight wilting of top leaves
** - light chlorosis of lower and top leaves (yellow-veining) and light wilting of leaves
*** - moderate chlorosis of leaves (general yellowing) and moderate degree of wilting, plant stunted (little growth)
**** - heavy chlorosis of leaves (yellow) and heavy wilting of plants (stems and leaves), no growth
***** - top leaves yellow, lower leaves necrotic, stems badly wilted, plant nearly dead
—— - death of plant

Table 4. Damage to Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when aphids were introduced on the plants at four weeks after plant emergence. Stillwater, Oklahoma. 1959.

Days after infestation	Damage Ratings			
	Four Weeks			
	Aphids Per Plant			
	1	10	25	40
1	0	*	*	*
2	*	*	**	**
3	**	**	***	***
4	***	***	***	***
5	***	***	****	****
6	***	***	****	****
7	***	****	****	****
8	***	****	****	****
9	***	****	*****	*****
10	****	****	——	——

0 - no visible damage
* - very light chlorosis of lower leaves and/or slight wilting of top leaves
** - light chlorosis of lower and top leaves (yellow-veining) and light wilting of leaves
*** - moderate chlorosis of leaves (general yellowing) and moderate degree of wilting, plant stunted (little growth)
**** - heavy chlorosis of leaves (yellow) and heavy wilting of plants (stems and leaves), no growth
***** - top leaves yellow, lower leaves necrotic, stems badly wilted, plant nearly dead
—— - death of plant

Table 5. Antibiosis of Buffalo and Cody alfalfa to the spotted alfalfa aphid <u>Therioaphis</u> <u>maculata</u> (Buckton) at emergence as expressed by the number of aphid reinfestations required to maintain aphid infestations. Stillwater, Oklahoma. 1959.

Days after infestation	Buffalo				Cody			
	Aphids Per Plant				Aphids Per Plant			
	1	2	3	4	1	2	3	4
1	0	0	0	0	2	1	0	0
2	0	0	1	0	3	2	1	3
3	0	0	0	0	3	1	1	2
4	0	0	0	0	1	1	0	1
5	0	0	0	0	3	1	1	2
6	0	0	1	0	2	1	1	1
7	0	0	1	0	1	1	0	2
8	0	1	1	0	3	0	3	1
9	0	2	4	0	2	3	1	0
10	0	1	4	5	3	1	1	3
Total plants reinfested	22				41			

Table 6. Antibiosis of Buffalo and Cody alfalfa to the spotted alfalfa aphid Therioaphis maculata (Buckton) at one week after plant emergence as expressed by the number of aphid reinfestations required to maintain aphid infestations. Stillwater, Oklahoma. 1959.

Days after infestation	Buffalo Aphids Per Plant 1	2	3	10	Cody Aphids Per Plant 1	2	3	10
1	3	1	0	0	2	1	0	0
2	4	0	0	0	4	0	3	0
3	1	0	0	1	1	3	1	0
4	2	0	0	0	2	3	1	2
5	1	0	0	0	2	3	1	2
6	0	3	2	2	1	2	2	2
7	1	0	0	0	2	1	1	0
8	1	0	0	0	0	1	0	0
9	0	0	0	0	1	0	0	1
10	1	0	0	1	2	1	0	1
Total plants reinfested	24				49			

higher tolerance for aphid feeding than did Buffalo. No visible damage could be seen in a typical plant which had been infested with one aphid (table 1). Three aphids per plant showed the heaviest damage. Three of the five replicates of this three-aphids-per-plant series were dead at 10 days (table 8).

Only six of the 20 Cody plants died during the test. Death and damage depended more upon the individual plant than upon the number of aphids infesting the plant. Some plants were dead in three days; others never showed any visible damage, regardless of the fact that they were more heavily infested than plants that died. Resistance in Cody, shortly after emergence, is apparently highly variable between individual plants in the variety. However, when compared to the susceptible variety, Cody was much more resistant.

Table 7. Mortality of Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when infested at emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	13	13	14	--	14-34
2	--	--	--	--	3
3	--	14-34	14-34	--	14-34
4	--	--	6	3	3

-- plants did not die
14-34 plant died in period from 14 to 34 days

Table 8. Mortality of Cody alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when infested at emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	--	--	--	--	--
2	--	--	--	3	34-46
3	10	--	--	3	10
4	--	34-46	--	--	--

-- plants did not die
34-46 plants died in period from 34 to 46 days

Susceptible Variety at One Week

Ten aphids per plant caused death of two of the five replicates in nine days and death of the other three replicates between nine and 20 days (table 9). All plants of this series were showing very severe damage at 10 days and severe damage from the seventh until the tenth day (table 2). The plants evidently lost their aphid infestation shortly thereafter and did not die for several days.

Death of plants infested with one, two, or three aphids per plant was delayed (table 9). However, two and three aphids per plant were causing severe damage at 10 days. Three aphids per plant began to show severe damage seven days after introduction of the aphids on the plants.

Three or more aphids per plant on alfalfa one week after emergence should be controlled. This number of aphids will cause severe damage to the alfalfa plants in a week. Plants thus damaged will recover very slowly, if at all.

Twenty-four plants required reinfestation during the 10-day period (table 6). In contrast to those plants infested at emergence, those infested with aphids one week after emergence did not require a greater number of reinfestations during the last few days. Rather, plants were reinfested periodically throughout the period.

Resistant Variety at One Week

Approximately twice as many (49) reinfestations were required for the Cody variety during the same period as with Buffalo (table 6). These older plants (one week post emergence) did not support aphid populations as well as did the Cody plants infested with aphids upon emergence.

Plant resistance to aphid populations, it seems, increases slightly with the age of the plant.

Only four of the 20 plants were killed by aphid feeding (table 10). Damage was most severe during the fifth and sixth day (table 2). However, at this time damage was not excessive. One plant succumbed to the aphids on the sixth day (table 10). Damage of the other plants decreased after the sixth day (table 2), but many of the plants remained infested. Three of these died 30 days after introduction of the aphids (table 10).

Although Cody plants did host light aphid infestations, only very slight damage could be seen in any of the plants at the end of 10 days. This fact further suggests that the major resistant quality of Cody is its tolerance to aphid feeding.

Susceptible Variety at Two Weeks

Ten and twenty aphids per plant began inflicting severe damage six days after aphids were introduced (table 3). Death of the plants occurred from seven to 12 days after introduction with 20 aphids per plant and from 11 to 12 days after introduction with 10 aphids per plant (table 11). Control measures should be undertaken when 10 or more aphids are found per plant on plants two weeks old.

It may be noted that damage caused by spotted alfalfa aphids is directly proportional to the number of aphids feeding upon the plant. However, twenty aphids per plant caused only slightly more damage (table 3) and increased the rapidity of death only slightly (table 11) over the 10-per-plant infestation. Plant damage is accelerated by an additional quantity of aphids above the 10-per-plant level, but at a slower rate than might be expected when the aphid infestation is doubled or tripled.

Death of plants infested with one or two aphids per plant was delayed for two to four weeks. However, both degrees of infestation showed severe damage in 10 days.

Susceptible Variety at Three Weeks

For some unknown reason, plants three weeks after emergence were very susceptible to aphid damage. Thirty aphids per plant killed plants in four to nine days, except in replicate five (table 12). This plant evidently displayed some individual resistance properties and did not succumb until the twenty-third day. Twenty aphids per plant killed plants in four to nine days; ten aphids per plant killed in 8 to 19 days. Even one aphid per plant brought plant mortality reasonably soon; most plants so infested were dead in 12 to 14 days.

Twenty and 30 aphids per plant caused severe damage to plants in three days (table 3). Plants infested with 10 aphids per plant showed severe damage in six days. Plants infested with 10 aphids or more per plant, three weeks after emergence, then, should receive application of a control agent.

Susceptible Variety at Four Weeks

Very little difference in rapidity of death of plants (table 13) or damage of plants (table 4) can be seen between the 25 and the 40 aphids-per-plant infestations. In eight of the 10 replicates, death resulted in seven to 13 days after introduction of the aphids. Death occurred at approximately the same time with the one and with the 10-

aphid-per-plant infestations (table 13). However, severe damage was noted on the seventh day after infestation with the 10-aphid-per-plant level but was not seen until the tenth day with the one-aphid-per-plant level.

The feasibility of control measures is questionable at the 10-aphid-per-plant level; however, at levels above 10 aphids per plant, control should certainly be initiated.

Summary:

When plants become severely damaged, aphid populations drop sharply or disappear completely. The plants may remain in a heavily damaged condition for several days, then die, or they may eventually recover from the damage.

Control procedures should be administered to Buffalo variety alfalfa when: (1) three aphids per plant are found upon emergence, (2) three aphids per plant found at one week, (3) ten aphids per plant found at two weeks, (4) ten aphids per plant found at three weeks, or (5) over 10 aphids found per plant at four weeks. Lighter infestations than these would warrant insecticide applications, however, if plants had been damaged badly by prior aphid feeding or some other condition that might have caused an unthrifty condition in the plant.

Cody alfalfa required approximately twice as many reinfestations as did Buffalo, indicating that repellency to aphids is one of its resistant properties. Probably a more effective resistant quality of this variety is its ability to tolerate a larger amount of aphid feeding, without excessive damage, than can a susceptible variety, such as Buffalo.

Damage is directly proportional to the number of aphids feeding upon the alfalfa plant. Plant damage is accelerated by an additional quantity of aphids above a certain point, but to double or triple the aphid number thereafter will not bring about proportional increase in damage of the plant.

Table 9. Mortality of Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), when infested at one week after emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	10-20	10-20	--	--	--
2	26	26	10-20	--	--
3	--	26	10-20	25	10-20
10	10-20	9	9	10-20	20

-- plants did not die
10-20 plants died in period from 10 to 20 days

Table 10. Mortality of Cody alfalfa plants caused by attacks of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), when infested at one week after emergence, Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	--	--	--	--	--
2	--	--	--	6	--
3	--	--	--	26-30	26-30
10	--	26-30	--	--	--

-- plants did not die
26-30 plants died in period from 26 to 30 days

Table 11. Mortality of Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when infested at two weeks after emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	17	23	30	13	30
2	17	18	17	23	17
10	12	12	12	11	11
20	7	12	8	9	8

Table 12. Mortality of Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when infested at three weeks after emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	14	12	23	14	14
10	8	19	8	8	8
20	6	7	4	6	9
30	4	6	7	9	23

Table 13. Mortality of Buffalo alfalfa plants caused by attacks of the spotted alfalfa aphid, Therioaphis maculata (Buckton), when infested at four weeks after emergence. Stillwater, Oklahoma. 1959.

	Days to Death of Plant				
	Replicate Number				
Aphids Per Plant	1	2	3	4	5
1	16	11	19	16	30
10	16	19	15	11	11
25	19	8	8	11	10
40	7	10	10	13	30

REPRODUCTION AT VARIOUS TEMPERATURE LEVELS

Lower mortality of the spotted alfalfa aphid from insecticides seems to be inevitable at lower temperatures. However, it may be possible that a very high mortality, normally associated with aphid control, is not necessary at these lower temperatures. It was shown by Dickson *et al.* (1955) and Nielson and Barnes (1957) that production of young was affected by temperature. The former authors pointed out that much higher reproduction of young occurs at higher temperatures than at low temperatures.

This test was conducted in order to determine the number of aphids produced per day by females at various temperature ranges. This information should be enlightening as to the approximate degree of mortality necessary for adequate control at the various temperatures tested. It may also help answer some of the questions of population trends connected with this insect.

Methods and Materials:

Aphids were counted at 24-hour intervals during the entire period. Each test, for any particular temperature range, was replicated 10 times.

Seven mean temperatures were used; these ranged from 25 to 85 degrees F., at 10-degree intervals. Tests for the temperature ranges 25, 35, 45, and 55 degrees F. were conducted in a refrigerator, calibrated each time for the desired temperature. The refrigerator was equipped with a special control thermostat which was calibrated for temperatures from 30 to 70 degrees F. The 65, 75, and 85 degree F. temperatures were maintained in a temperature cabinet, heated by an incandescent light bulb which was connected to a thermostat, capable of being adjusted to the desired temperature.

Temperatures were recorded constantly throughout the test period by means of a thermograph. Temperatures fluctuated $\pm$ four degrees F. from the mean in the refrigerator and a $\pm$ two degrees in the temperature cabinet.

In all except the 25-degree range, bouquets of Oklahoma Common alfalfa were used as hosts for the aphids. Bouquets were made by wrapping the stems of alfalfa leaflets with cotton and placing these stems in a vial of water. This practice was used to keep alfalfa green and palatable to the aphids. Alfalfa bouquets were placed in half-pint ice-cream cartons, to which an aphid was introduced, then placed in the refrigerator or temperature cabinet. Bouquets of fresh alfalfa were placed in the cartons every two days.

Alfalfa bouquets employing vials of water could not be used at the 25-degree F. level, so a slightly different method was used at this temperature. In this test, leaflets of Oklahoma Common variety were placed in petri dishes; the leaflets being replaced with fresh ones each day. An aphid was introduced into each petri dish, as with the ice-cream cartons, and placed in the refrigerator.

Both alate and apterous female aphids of approximately equal age were used. Of these, 75 per cent were apterous. At the beginning of each emperiment, one female was introduced into each of the containers. If an adult aphid was found dead at any period in the test, it was replaced by a live adult.

Live and dead adults and nymphs were counted daily. Data concerning the activity and habits of the insects were also noted. Reproduction was expressed as the number of aphids produced per day per adult female over a seven-day period. The per cent mortality was derived by dividing the total number of aphids in each temperature test (includes number introduced, replacement for dead, and number of young produced) into the total number of aphids which died during the particular temperature study. The aphid population was calculated as the sum of the number initially introduced and the number produced minus the number dead. Populations thus obtained were expressed as 1/100 of the total population in order that the population figure might be placed in the table with reproduction and mortality.

Results:

Reproduction was lowest at the 25 degree F. level and increased with an increase in temperature to the 75 degree F. level. At the 85-degree temperature, reproduction decreased to a point slightly below that for the 65 degree mean temperature test. Mortality was highest at 85 degrees F. and lowest at 55 degrees. Aphid feeding and activity were reduced at temperatures of 25 and 35 degrees, but aphids were observed feeding vigorously at 45 degrees F. and above.

At 25 degrees F., production of young was practically at a standstill (.028 aphids per day). The mortality rate was much higher than the reproduction rate at this temperature. Aphid populations then, when exposed to temperatures from 20 to 30 degrees F. for a period of a week, would be expected to drop substantially. It should be noted, however, that diurnal fluctuations of temperature in Oklahoma would usually allow certain periods of feeding and reproduction during each day. Long periods of this low temperature would theoretically eradicate the aphid population. This is, no doubt, what happens in the northern range of distribution of the spotted alfalfa aphid, where populations are destroyed during the winter but migrate back into the region from warmer areas in the spring to reinfest alfalfa fields.

Aphid activity was also materially decreased at 25 degrees F. Aphids were inactive and appeared dead immediately after removal from the refrigerator. However, when they were moved to a room in which the temperature was approximately 80 degrees F., movement of the antennae and legs could be seen after a period of 20 to 30 minutes. At this low temperature, very few aphids were found feeding. Most were found in the bottom of the petri dish each time the aphids were counted during the seven-day observation period.

Based upon this observation, it is probable that aphids feed for short periods of time, obtaining enough nourishment to maintain life at the 25-degree temperature. Body metabolism is undoubtedly progressing at a very slow rate of this temperature, so only a small amount of food is needed to maintain life. Lack of activity is another factor that limits the need for large amounts of food, which is normally associated with the feeding habits of this insect at higher temperatures.

Because of the low feeding level at a temperature of 25 degrees F., it is likely that the aphid does very little damage to alfalfa plants when temperatures are 30 degrees or below. Due to the small amount of damage caused by feeding of the aphids and the prospect of a low level of aphid mortality by insecticides, it is doubtful that chemical control measures are feasible in the 20 to 30 degree F. temperature range.

During the experiment at a mean temperature of 35 degrees F., reproduction was very low, although slightly higher than at the 25-degree level. Mortality dropped considerably (50 to 20 per cent) with an increase in temperature from 25 to 35 degrees F. The same number of aphids died as were produced at the 35-degree temperature.

It was noted that aphids did more feeding at 35 degrees than at 25 degrees F., but even at the former temperature, much more time was spent on the bottom of the ice-cream carton than on the alfalfa leaflets. There was a great deal of increase in aphid activity from the 25-degree to the 35 degree level, which probably necessitates an increase in time spent by the aphids in feeding.

Populations should remain fairly constant at 30 to 40 degrees F. Because of this theoretical population stability the low rate of plant growth, and the level of aphid activity, chemical control should be considered at this temperature. Although effective aphid control must approach 100 per cent mortality under conditions most favorable for aphid population increase, several factors may work to lower the degree of control necessary at 35 degrees F. The lower rates of aphid reproduction and feeding suggest that 80 to 85 per cent control would probably be more effective in reducing aphid populations to non-economic levels at this temperature than a 99 per cent control would at 65 or 75 degrees F.

Both reproduction and mortality increased at a mean temperature of 45 degrees F. Approximately the same number of aphids died as were produced and aphids were found to spend much time feeding on alfalfa leaflets. The population would be expected to remain fairly constant, as was the case with the mean temperature of 35 degrees. Chemical control should definitely be employed when temperatures range from 40 to 50 degrees and when aphid populations are at economic levels, even though control might not be as good as would be most desirable.

Mortality reached its low point of 18.8 per cent in the test at 55 degrees F. Reproduction increased greatly (from .143 to .585 aphids per day) from the 45-degree level. Almost all aphids were found feeding on alfalfa leaflets at this temperature. Providing other conditions were not detrimental, aphid populations should begin an increase in the field at 55 degrees F. High mortality from chemical control would be necessary to suppress aphid populations at this temperature.

Because of the high reproduction rate and low mortality at 65 degrees, aphid populations reached their peak. Aphid reproduction increased more from the 55 to the 65-degree level than for any other range in the test. If 60 to 70-degree temperatures were to persist for a long period of time, control from chemicals would be effective only when insecticides rendered near 100 per cent mortality and would probably have to be repeated if residues did not persist.

Reproduction reached its peak of 2.40 young per day at 75 degrees F. Mortality, however, increased with the 10-degree increase in temperature so that populations were slightly lower for this level than at 65 degrees F.

When hot weather persists day and night for a period of several days, spotted alfalfa aphid populations decrease rather rapidly in the field. The 85-degree F. data will help explain this phenomenon. At 85 degrees, reproduction dropped to a point below that of the 65-degree level and mortality reached its high (56.6 per cent) for the test period. This combination caused populations to take a sharp drop, comparable to those noted in the field (table 14).

Summary:

Reproduction was lowest at a mean temperature of 25 degrees F. and increased with an increase in temperature to 75 degrees F. At 85 degrees, however, reproduction decreased to a point slightly below the 65-degree level. Reproduction reached its peak at 75 degrees F. Mortality was lowest at 55 degrees F. and highest at 85 degrees F.

Aphid populations reached their maximum at 65 degrees F. and a point of extinction was reached at 25 degrees F. Activity and aphid feeding increased with an increase in temperature, from essentially dormancy at 25 degrees to an active and vigorously feeding population at temperatures of 45 degrees and above.

Because of a declining population, lack of normal aphid feeding habits, and low mortality from insecticides at 25 degrees F., chemical control does not seem feasible at this temperature level; even at 35 degrees F., it is questionable. Control should be encouraged, however, when populations reach economic levels at temperatures at or above 45 degrees F.

Table 14. Reproduction, mortality, and population levels of the spotted alfalfa aphid, _Therioaphis_ _maculata_ (Buckton), under constant temperature conditions. Stillwater, Oklahoma. 1959.

Temperature (Degrees F.)	Reproduction (Progeny Per Day Per Female)	Mortality (Number Dead Over Total Used)	Population (Parents Plus Progeny Minus Dead Over 100)
25 ± 4	0.028	50.0	0.00
35 ± 4	0.043	20.0	0.10
45 ± 4	0.143	48.0	0.08
55 ± 4	0.585	18.8	0.41
65 ± 2	1.985	23.8	1.43
75 ± 2	2.400	36.8	1.08
85 ± 2	1.914	56.6	0.68

CONTACT INSECTICIDE TESTS AT LOW TEMPERATURES

Since the spotted alfalfa aphid appeared in Oklahoma, much chemical control work has been done at temperatures ncrmal to the area for the months of April and May. Several insecticides have proved effective under these late spring conditions. During the late winter and early spring when temperatures range below 60 degrees F., chemical control of the spotted alfalfa aphid is very difficult to attain. At these temperatures, the effectiveness and speed of action of most insecticides is greatly reduced. However, due to the fact that aphid reproduction is also reduced at low temperatures, mortality of aphids will not necessarily need to be as complete as would be required for adequate control at higher temperatures.

Behavior of insecticides at these lower temperatures is often unorthodox so that many results from insecticide tests will not be comparable to results from moderate or high temperature insecticide tests. Results from the following series of chemical tests will show discrepancies. Some of these contradictions and variances can be reconciled, but others are without apparent explanation.

Methods and Materials:

A series of insecticide experiments was begun in January, 1959, to evaluate effectiveness of insecticides under low temperature conditions, for control of the spotted alfalfa aphid. This series of tests included four small-plot tests and one large-plot test in a mean temperature range between 34.3 and 65.5 degrees F.

All tests were conducted on an alfalfa field approximately four miles west and one mile north of Stillwater, Oklahoma. A seven-day recording thermograph was established in approximately the median position of the test area. The thermograph element was placed on the soil surface and protected from the direct rays of the sun by a shade. The shading device was open on all sides in order that currents of air could circulate unobstructed around the element.

The thermograph used did not function properly during a period from February 11 to February 14 and from April 24 to May 5. This period included portions of time when insecticide tests were being conducted; therefore other sources of temperature data were employed for the missing period.

Temperature data for the period from February 11 to February 14 were procured from another agency of the University. Regardless of the fact that the latter thermograph was located four feet above the soil surface, data from this instrument were surprisingly similar to those taken in the test field at soil surface level. Therefore, they were used without correction.

Temperature data for the period from May 1 to May 5 were obtained from the Weather Bureau (U. S. Dept. of Commerce, 1959). These data were correlated with the test field data for a 53-day period in the months of February, March, and April. In order to adjust Weather Bureau data to that taken in the test field, 10 degrees F. was subtracted from the maximum temperature and nine degrees F. was subtracted from the minimum.

The climatological data for these tests are expressed as maximum, minimum, and mean temperatures. Maximum temperature is the highest temperature recorded in each test period and minimum temperature is the lowest temperature recorded during any particular test (this is true regardless of the data source). Mean temperature data from the test field and the other university agency are derived by dividing the sum of the daily two-hour temperature readings by 12. Mean temperature from the Weather Bureau, however, is the sum of the maximum and minimum temperatures, divided by two. The latter calibration is the standard Weather Bureau method used to obtain mean temperature.

Effectiveness of insecticides is expressed as per cent control. These figures were computed by Abbott's Formula (Abbott, 1925) which relates the infestation counts in the treated areas to the rise or fall in the population of the untreated plots.

Small-plot Tests

Test plots were staked off with a yard square quadrat[1]. Each of the tests consisted of forty square-yard plots situated in an "L" shape. Twenty of these plots were in a line running east and west, whereas the other twenty plots were in a line running north and south. This arrangement was used for the purpose of avoiding insecticide contamination caused by wind blowing longitudinally down the test plots. Treated plots were separated by a square-yard area to prevent contamination by drift of the insecticide at the time of application.

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[1]A yard square frame made to facilitate rapid staking of plots.

Each insecticide treatment was replicated twice, one replicate on each side of the "L". In Tests I, II, and III, one check replicate was located on each side of the "L". However, in Test IV the plot between treated areas was used as a check, so that each side contained 10 check plots.

Plots were sprayed with a one-gallon compressed air sprayer, using a 2X cone-type nozzle. Precautions were taken to rid the sprayer of insecticide contamination after the use of each insecticide. Measures were also taken to keep the pressure as constant as possible in each of the treated plots.

Four seconds were required for adequate coverage of the square-yard plots. Approximately 6.5 ml. of material was delivered by the nozzle in the four-second period at the standardized pressure. On an area basis, this was the equivalent of approximately eight gallons of spray mixture.

A total of 28 insecticides were used in the four tests. These were: SEVIN (N-methyl-1-naphthyl carbamate), heptachlor (1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-endomethanoindene), endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-dimethanonaphthalene), dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-dimethanonaphthalene), malathion (bis(ithoxy-carbonyl) ethyl dimethyl thiophosphate), DI-SYSTON (0,0-diethyl 5-2-(ethylthio) ethyl phosphorodithioate), demeton (0,0-diethyl 0-[2-(ethylmercapto) ethyl] thiophosphate), THIMET (0,0-diethyl S-(ethyl thio methyl) phosphorodithioate), dicapthon (0,0-diethyl 0-(2-chloro-4-nitrophenyl) phosphoro-thionate), Union Carbide 8305 (P-chloro-2,4-dioxa-5-methyl-P-thiono-3-Phosphobicyclo (4,4,0) decane), parathion (0,0-diethyl-0-p-nitrophenyl thiophosphate), methyl parathion (0,0-dimethyl-0-p-nitrophenyl thiophosphate), phosdrin (dimethyl 1-

carbomethoxy-1-propen-2yl phosphate), Shell BAS 4092 (Benzyl 3(dimethoxyphosphinyloxy) crotonate), Shell BAS 4239 (p-Chlorobenzyl 3(dimethoxyphosphinyloxy) crotonate), Shell BAS 3423 (2-Acetoxyethyl 3(dimethoxyphosphinyloxy) crotonate), Shell SD 4402 (1,2,3,4,5,6,7,8-Octachloro-3a,4,7,7a-tetrahydro-4,7-methanophthalan), and DIBROM (O,O-dimethyl O-(2,2-dichloro-1,2-dibromoethyl) phosphate).

Other insecticides used in the tests were: PHOSPHAMIDON (O, O-dimethyl O-(2-chloro-2-diethylcarbamoyl-1-propen-2-yl) phosphate), DIAZINON (O,O-diethyl O-(2-isopropyl-4-methyl-6-primidinyl) phosphorothioate), CHLORTHION (O,O-dimethyl-O-(3 chloro-4-nitrophenyl) thiophosphate), American Cyanamid 18706 (O,O-dimethyl S(N-ethyl-carbamoyl-methyl) phosphorodithioate), dimethoate (O,O-dimethyl S(N-methylcarbamoyl-methyl) phosphorodithioate), KORLAN (O,O-dimethyl-O-2,4,5-trichlorophenyl phosphorothioate), PERTHANE (Diethyl diphenyl dichloroethane), RHOTHANE (Dichlorodiphenyl dichloroethane), thiodan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodiodioxathiepin-3-oxide), and TRITHION(O,O-diethyl S-p-chlorophenylthiomethyl phosphorodithioate).

All insecticides were applied as emulsifiable concentrates, with the exception of SEVIN 85 per cent sprayable powder, thiodan miscible, TRITHION flowable, and malathion dissolved in Soltrol, an iso-paraffin oil. Soltrol alone was also used in one test. Malathion was applied at the rate of one-half pound of actual per acre; SEVIN was applied at the rate of one pound of actual material per acre. Other insecticides were applied at the rate of one-fourth pound actual per acre.

In Tests I, II, and III, the number of aphids found on 15 leaves, picked at random over the plot, constituted the aphid count for each plot. However, the Henderson Fork Sampler (Henderson, 1956) was used as the sampling instrument on Test IV when the alfalfa had grown sufficiently for this method to be used.

In each of the tests, pre-treatment counts were taken 24 hours prior to treatment. Both pre-treatment and post-treatment counts were made in all plots in the first three tests. In Test IV, pre-treatment counts were taken in the check plots (areas between treated plots) only. Pre-treatment counts were then derived from the mean of the two check plots adjacent to treated areas. Post-treatment counts were taken in all plots. These counts were taken at various intervals, depending on weather conditions in the field, although a one, seven, and fourteen-day schedule was planned originally. Snow and rain often prevented sampling at the desired time.

Test I.

Post-treatment counts were taken at one, seven, and fourteen-day intervals. Adverse weather conditions caused a drop in the aphid count in the check blocks soon after treatment. A blanket of snow covered the ground approximately seven hours after application of the insecticides. This snow covered the ground and the small alfalfa for approximately two and one-half days before melting. On the sixth day after treatment, snow again covered the ground, lasting only a few hours. Post-treatment counts in the check, between the seventh and fourteenth day, showed a further decrease because of rain and drizzle which occurred intermittently throughout the period.

The mean temperature for the 14-day period was 34.3 degrees F., varying from a low of eight degrees F. shortly after treatment, to a high of 71 degrees F. on the seventh day after insecticide application.

Insecticides used in the test were: demeton, THIMET, Union Carbide 8305, parathion, methyl parathion, endrin, malathion, DIBROM, and dicapthon.

Test II.

Only two post-treatment counts were taken on this test, at two and at ten days after chemical application. Adverse weather conditions also affected the untreated aphid population in this test. Snow began to fall approximately 10 hours after application of insecticide and continued to lay on the soil surface for about one and one-half days before melting. Between the second and ten-day post-treatment counts, rain and drizzle occurred continuously to cause a further decrease in the infestation counts in the untreated blocks.

The mean temperature for this 10-day period was 38.3 degrees F., varying from a low of 12 to a high of 71 degrees F.

The same insecticides were used in this test as in Test I, namely: demeton, THIMET, Union Carbide 8305, parathion, methyl parathion, endrin, malathion, DIBROM, and dicapthon.

TEST III.

Again only two post-treatment counts were made. The first, one day after treatment and the second, seven days after treatment. Weather was fair for approximately 24 hours after the insecticides were applied. Aphid counts in the check increased during this time. However, between the first and the seventh day, rain and drizzle again caused a sharp decrease in the untreated plots. Temperature varied from a high of 71 degrees F. during the first 24 hours after application, to a low of 18 degrees F. on the fourth day after treatment. The mean temperature for this period was 41.1 degrees F.

Insecticides used in this test were: American Cyanamid 18706, dimethoate, KORLAN, PERTHANE, RHOTHANE, DIAZINON, PHOSPHAMIDON, dicapthon, and Shell BAS 3423.

Test IV.

Post-treatment counts were made 24 hours after treatment. Counts were also made 48 hours after treatment, at which time counts in the untreated areas were very low. Because of these very low check counts, an accurate evaluation of insecticidal control was impossible, so the 48-hour post-treatment counts were not recorded. This rapid decrease of aphids in the untreated plots was believed to be due to heavy winds and high humidity. The high temperature was 62 and the low was 29 degrees F., with a mean of 42.6 degrees F.

Insecticides used in Test IV were: SEVIN, malathion, demeton, THIMET, Union Carbide 8305, parathion, methyl parathion, endrin, phosdrin, Shell BAS 4092, Shell BAS 4239, Shell BAS 3423, Shell SD 4402, soltrol, malathion dissolved in soltrol, DIBROM, PHOSPHAMIDON, dicapthon, DIAZINON, CHLORTHION, American Cyanamid 18706, dimethoate, KORLAN, PERTHANE, RHOTHANE, dieldrin, heptachlor, thiodan, and TRITHION.

Large-plot Test

Nine of the more promising insecticides from small-plot tests were evaluated on a large area for a more accurate determination of effectiveness. Each insecticide-treated plot was replicated four times with four untreated plots. Each plot was 22 feet wide and approximately one-fourth acre in size.

Aphid counts were made with the Henderson Fork Sampler (Henderson 1956). Four series of slides were taken at random over each quarter-acre plot. Pre-treatment counts were taken on two of the sets of replicates three days prior to treatment and on the other replicates two days prior to application of test chemicals. Part of one replicate of the SEVIN-treated plot had been sprayed with parathion six days before application of test insecticides. This area was excluded from the sampling area.

Test plots were sprayed with a jeep sprayer[1], calibrated to apply eight gallons of spray concentrate per acre. The spray applicator was regulated to hold pressure constant at 65 p.s.i. The spray boom was fitted with six g.p.m. cone-type nozzles set at 18-inch intervals on the 22-foot boom.

All insecticides used were in the form of emulsifiable concentrates, with the exception of: TRITHION flowable, thiodan miscible, and SEVIN 85 per cent sprayable powder.

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[1]A jeep FWD pick-up truck with engine governor converted for use as a spray truck; the spray-pump driven by a gasoline engine, and a spray-tank installed in the back of the vehicle. The three-piece spray boom was located in front of the jeep.

SEVIN was applied at the rate of one pound actual per acre, and malathion was applied at the rate of one-half pound actual per acre. All other materials were applied at the rate of one-fourth actual pound material per acre. Nine insecticides were used in the test. These were: DIBROM, dimethoate, dicapthon, malathion, Shell SD 4402, thiodan, TRITHION, DIAZINON, and SEVIN.

Post-treatment counts were made at three days and at four days after insecticide application. Scattered showers fell during the sampling of three of the sets of replicates on the four-day count. Beating rains thereafter prevented further sampling of the test plots. Evaluations are presented as per cent control, computed using Abbott's Formula (Abbott, 1925).

Results:

Temperature Range: 30 to 40 Degrees F.

Two tests were conducted at a mean temperature range of 30 to 40 degrees F. However, somewhat different results were obtained, which correspond to some degree with the difference in temperature between post-treatment counts. The mean temperature for the first two days of Test I was 20.2 degrees F. and 34.3 degrees F. for the entire 14-day period (table 15). The average mean temperature in Test II was 38.3 degrees F. for the 10-day test. The data taken during Test II show a higher mean temperature (28.8 degrees F.) for the first two days than did Test I. This increase of eight degrees in temperature resulted in a great deal of increase in effectiveness in insecticides (tables 16 and 17).

At the very low temperature of 20.2 degrees F. (two days post

Table 15. Mean temperatures for various periods during each of five insecticide tests for control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), Stillwater, Oklahoma. 1959.

Mean Temperature During the Period From:	Test Number				
	I	II	III	IV	V
Application to first post-treatment count	20.2	28.8	41.4	42.6	66.6
First post-treatment to second post-treatment count	31.0	40.6	40.0	--	62.0
Second post-treatment to third post-treatment count	40.7	--	--	--	--
Entire test period	34.3	38.3	41.1	42.6	65.5

-- data were not taken during this period

Table 16. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), with contact insecticides at various periods after application. (Test I) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 2 days	7 days	14 days
Demeton	0.0	0.0	68.9
THIMET	0.0	12.5	87.3
Union Carbide 8305	0.0	86.2	81.5
Parathion	51.9	96.9	91.9
Methyl parathion	0.0	100.0	100.0
Endrin	0.0	20.6	74.3
Malathion	7.9	68.4	100.0
DIBROM	0.0	35.4	100.0
Dicapthon	0.0	94.1	86.0

Table 17. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), with contact insecticides at various periods after application. (Test II) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 2 days	Per Cent Control at 10 days
Demeton	79.9	90.5
THIMET	75.3	79.5
Union Carbide 8305	83.9	95.6
Parathion	40.0	94.5
Methyl parathion	82.1	100.0
Endrin	79.1	94.2
Malathion	0.0	73.1
DIBROM	52.0	73.4
Dicapthon	64.0	100.0

treatment, Test I), only parathion showed any appreciable control, although malathion caused some mortality. Neither of these insecticides, however, rendered satisfactory control at this exceptionally low temperature. The two-day post-treatment count from Test II shows much more control than for the corresponding count in Test I, due presumably to the increase in temperature. Although no insecticide showed adequate mortality at this point in Test II, demeton, THIMET, Union Carbide 8305, methyl parathion, and endrin did show much promise.

The mean temperature between the first and second post-treatment count of Test I was 31.0 degrees F. Adequate control was obtained during this time with three insecticides (table 16). Methyl parathion gave excellent control, and ethyl parathion and dicapthon rendered good control. Union Carbide 8305 showed promise, but was not effective enough to be considered adequate for aphid control. All insecticides, except demeton, showed some degree of control at this period. This indicates that demeton kills at a very slow rate at low temperatures, probably because of a reduction in volatility at low temperatures which affects the initial kill rendered by this insecticide. The systemic action of demeton may also be affected by lower temperatures. This may be caused by a decrease in movement of fluids within the plant and a decrease in speed of conversion of demeton to systemic metabolites within the plant.

Aphid samples were not taken at seven days in Test II, but at 10 days after insecticide application. Results at this point correspond, to a large degree, with those of the 14-day count of Test I. At a mean temperature of 40.6 degrees between the second and ten-day count, five insecticides rendered effective control. Methyl parathion and dicapthon rendered 100 per cent control at this point, and parathion, Union Carbide 8305, and endrin displayed adequate control. The mean temperature increased to 40.7 degrees F. before the last count was taken on the fourteenth day. During this period, four insecticides obtained adequate to excellent control. These were: parathion, methyl parathion, malathion, and DIBROM. THIMET, Union Carbide 8305, and dicapthon displayed only fair control in this test.

During 14 days following treatment, many insecticides would be expected to lose their effectiveness. This is probably the case with dicapthon, endrin, and Union Carbide 8305, where effectiveness of these chemicals was lower at the 10-day count of Test I (table 16). It is somewhat surprising, however, that DIBROM and malathion should increase in effectiveness from only fair mortality at a 10-day count (Test II, table 17) to excellent at a 14-day count (Test I, table 16).

Results from Test II show all insecticides increasing in effectiveness from the two-day to the ten-day count; however control from dicapthon, parathion, and Union Carbide 8305 decreased slightly from the seven-day to the 14-day post-treatment count in Test I. Although there was a rise in mean temperature between these counts (from 31 to 40.7 degrees F.), it is not likely that this increase caused the insecticides to volatilize to any appreciable extent. Decrease in effectiveness was probably caused by hydrolysis of the material or a normal variation in sampling.

Temperature range: 40 to 50 degrees F.

Two small plot insecticide tests were conducted with temperatures at this range. In Test III, the mean temperature averaged 41.4 degrees F. for the two days prior to the first post-treatment count and 41.1 degrees F. for the entire seven-day period. Only one post-treatment count was taken in Test IV, that at one day. The mean temperature for this period was 42.6 degrees F.

Data from post-treatment counts taken one day after insecticide application show effective control from four insecticides. In Test III, KORLAN and PERTHANE rendered effective control (table 18). CHLORTHION and DIBROM gave high mortality, in Test IV, for the one-day period (table 19a). Several other insecticides gave fair control at this time. These were: American Cyanamid 18706, dimethoate, RHOTHANE, DIAZINON, PHOSPHAMIDON, American Cyanamid 4124, and Shell BAS 3423 (tables 19a and 19b).

RHOTHANE, DIAZINON, American Cyanamid 4124, and Shell BAS 3423, which rendered moderate to good mortality in Test III, appeared as poor control agents in Test IV. It is also interesting to note that these insecticides, with the exception of Shell BAS 3423, displayed poor control at the seven-day post treatment count in Test III. These four chemicals, then, do not seem promising as control agents at 40 to 50 degrees F.

It may be noted in Test IV that parathion, methyl parathion, and malathion rendered no control at one day (table 19b). This may be explained by comparison with Test I (table 16) and Test II (table 17). In both of these tests, these three chemicals displayed little or no control at two days after application of insecticides. However, parathion and methyl parathion were providing good to excellent control at the seven, ten, and fourteen-day post-treatment counts. Malathion showed fair to excellent control for the same periods.

Table 18. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), with contact insecticides at two periods after application. (Test III) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 2 Days	Per Cent Control at 7 Days
American Cyanamid 18706	86.6	63.5
Dimethoate	81.7	92.7
KORLAN	97.2	100.0
PERTHANE	95.8	100.0
RHOTHANE	86.8	23.8
DIAZINON	86.0	14.1
PHOSPHAMIDON	82.2	94.9
American Cyanamid 4124	81.3	77.1
Shell BAS 3423	88.9	91.3

Malathion, in Test III (table 18), which was dissolved in soltrol instead of emulsified in water, gave a much higher kill of aphids than malathion alone. It may be seen in this test that soltrol alone renders moderate mortality at these temperatures. This suggests the possibility of increasing the per cent mortality and decreasing the time required for adequate control by insecticide solutions in soltrol.

Temperature Range: 60 to 70 Degrees F.

Only one insecticide test was conducted at this moderate temperature range. Mean temperature for this test, a large-plot experiment, was 65.5 degrees F. for the entire period. The results were disappointing. Some of these more promising insecticides, selected from results of small-plot tests, were expected to render much better control, especially at this higher temperature. Because of this increase in temperature, insecticides could be expected to exhibit faster action, so that at a four-day post-treatment period, a number of the selected chemicals were expected to show good control.

No insecticide displayed effective control in this test at either the three or the four-day count (table 20). Malathion, however, rendered best control in both post-treatment counts. It was the only insecticide that showed a near adequate control at four days after application of insecticides.

Dicapthon and dimethoate showed promise of an adequate control at the end of three days. However, data taken the following day showed a decrease in the per cent control, rather than an expected increase. Mortality at both post-treatment sampling periods was moderate, but not adequate, for thiodan and TRITHION. DIBROM,

Table 19a. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), with contact insecticides at 24 hours after application. (Test IV) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 24 Hours
Shell BAS 4239	75.9
Shell BAS 3423	67.0
Shell SD 4402	75.9
Soltrol	68.7
Malathion and soltrol	80.0
DIBROM	95.1
PHOSPHAMIDON	86.8
Dicapthon	87.0
DIAZINON	50.0
CHLORTHION	97.8
American Cyanamid 18706	83.6
Dimethoate	86.9
KORLAN	68.6
PERTHANE	37.3

Table 19b. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), with contact insecticides at 24 hours after application. (Test IV) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 24 Hours
RHOTHANE	66.7
Dieldrin	0.0
Heptachlor	5.2
Thiodan	17.0
TRITHION	29.8
SEVIN	16.6
Malathion	0.0
Demeton	8.9
THIMET	82.5
Union Carbide 8305	69.3
Parathion	0.0
Methyl parathion	0.0
Endrin	83.9
Phosdrin	83.7
Shell BAS 4092	0.0

Table 20. Control of the spotted alfalfa aphid, <u>Therioaphis maculata</u> (Buckton), with contact insecticides at two periods after application. (Test V) Stillwater, Oklahoma. 1959.

Insecticide	Per Cent Control at 3 Days	Per Cent Control at 4 Days
DIBROM	45.9	1.3
Dimethoate	86.5	68.2
Dicapthon	87.6	45.4
Malathion	87.5	84.2
Shell SD 4402	38.0	25.0
Thiodan	65.0	71.4
TRITHION	74.1	71.6
DIAZINON	63.6	30.8
SEVIN	5.0	16.0

DIAZINON, Shell SD 4402, and SEVIN rendered poor results at three and at four days.

Summary:

At 30 to 40 degrees F., methyl parathion was the only insecticide that consistently gave excellent mortality. This material is not effective at two days but does show 100 per cent control at seven, ten, and fourteen days after application of insecticides. For the same period, ethyl parathion rendered adequate control, especially at this low temperature when aphid reproduction is very low. Dicapthon was also very promising.

At the 40 to 50 degree level, KORLAN and PERTHANE rendered excellent control at seven days. PHOSPHAMIDON was also adequately effective at this time. Although somewhat lower than normally considered as effective aphid control, Shell BAS 3423, and dimethoate rendered good mortality.

Control of aphids at 60 to 70 degrees F. was disappointing. None of the nine insecticides tested at this temperature range proved to be effective aphicides. Malathion delivered the best moderate temperature results. DIBROM, which showed good control at low temperatures, was ineffective at moderate temperatures. Malathion also exhibited a higher per cent mortality at lower temperatures than at moderate temperatures.

Malathion dissolved in soltrol rendered a higher and a faster mortality than malathion alone. This suggests the use of soltrol as a carrier for insecticides, rather than water, for cold weather chemical control agents.

SYSTEMIC SEED TREATMENT

Treatment of alfalfa seed with systemic materials, if effective, would be an ideal means of applying insecticide for control of the spotted alfalfa aphid. Arthropod species, predaceous and parasitic upon the aphid would not suffer mortality from insecticide applications employing seed treatment. A systemic, applied to the seed, would also be effective in controlling the pest when temperatures were too low for efficient action by contact insecticides.

Systemic materials applied to alfalfa seed on activated charcoal have not proved as effective as might be desirable. Because of the small size and smooth seed coat of the alfalfa seed, only small amounts of insecticide are retained on the seed. This small quantity does not afford adequate control of the aphid for a period sufficiently long for seedling alfalfa plants to become established.

It seems reasonable to assume that if a greater quantity of insecticide could be retained on the seed, a longer and more efficient control would result. Hydroxyethyl cellulose (CELLOSIZE by Union Carbide Chemicals Company) and methyl cellulose were used as adhesive agents in this series of tests. Various concentrations of THIMET and DI-SYSTON (see page 46 for chemical names of both compounds), applied to the seed on activated charcoal alone or employing one of the two stickers mentioned above, were evaluated and compared to the control of a resistant variety.

When aphid populations were very high, results from systemic seed treatments were somewhat disappointing. Because of these poor results, high density aphid populations were introduced on plants of a resistant variety and on plants grown from seed treated with systemic insecticide. From a preceding test (Test I), it was learned that treatment of seed with systemic materials would protect seedling alfalfa plants from moderate aphid infestations. The purpose of this experiment, however, was to determine the effectiveness of systemic seed treatment against heavy aphid infestations.

Methods and Materials:

A series of three systemic seed treatment experiments (Tests I, II, and III) were conducted in a greenhouse in 1959. Each test consisted of checks and a number of seed treatments, replicated 10 times each. Results are expressed as per cent control, computed by Abbott's Formula (Abbott, 1925).

Various concentrations of THIMET and DI-SYSTON were tested using activated charcoal alone, activated charcoal pelleted with five per cent (by weight) of hydroxyethyl cellulose, and activated charcoal pelleted with two and one-half per cent (by weight) of methyl cellulose.

In the case of activated charcoal alone, one pound of alfalfa seed was placed in a gallon jar, to which was added the desired amount of insecticide. This material was shaken vigorously by hand to insure uniform distribution of systemic insecticide throughout the alfalfa seed. The treated seed was then sacked for future use in seed treatment tests.

Treatment with charcoal impregnated insecticides pelleted on the seed was similar to that of charcoal alone. Hydroxyethyl cellulose and methyl cellulose were dissolved in lukewarm water (approximately 130 degrees F.). One pound of seed, the desired amount of insecticide, and 45 ml. of five per cent hydroxyethyl cellulose or two and one-half per cent methyl cellulose were introduced into a gallon jar. These materials were mixed thoroughly by agitating the jar. The treated seed was then spread out on wrapping paper to dry before being sacked for later use.

In Tests I and II, twenty seeds of Oklahoma Common Alfalfa were planted in two rows across an ordinary six-inch flower pot. Approximately 20 to 30 seeds of Buffalo Alfalfa were planted in the same manner in Tests III and IV. The effect of systemic insecticides upon emergence of the alfalfa seedlings was recorded in Tests I and II.

When alfalfa seeds were planted at the beginning of Tests III and IV, they were believed to be of the Oklahoma Common variety (as were those in Tests I and II). However, it was learned several weeks later that these seeds were Buffalo variety of alfalfa. This change in variety may account for some difference in protection of plants from aphid infestations. Oklahoma Common variety alfalfa is more susceptible to attacks of the spotted alfalfa aphid than is Buffalo variety. Plants in Tests III and IV, then, received some degree of added protection which was not afforded to plants in the first two tests.

Plants were counted shortly after emergence and aphids were placed on each pot if aphid populations were not already well established in the greenhouse. Plants and aphids per pot were counted and recorded twice weekly during the test period. Colored pictures were taken in

Tests I and IV to show a comparison of control by the various agents. Pictures were taken 41 days after emergence in Test I and 40 days after emergence in Test IV.

Test I

This test extended over a period of 54 days after emergence of the alfalfa. Every other pot was infested with one aphid per pot, two days after emergence. Those pots not infested after nine days post emergence were inoculated with one aphid per pot. To prevent damage to aphids during transfer from host alfalfa to test pots, aphids were transported on alfalfa leaflets and were not touched during the transfer. At the end of the test (54 days post emergence), the aphid population had reached an average of 150 aphids per plant, which was the heaviest infestation recorded during the test period.

In this experiment, one and two pounds of actual DI-SYSTON and 0.88 and 1.76 pounds of actual THIMET per 100 pounds of Oklahoma Common variety alfalfa seed were applied on activated charcoal alone. The same concentrations of these two materials, formulated in 50 per cent activated charcoal DI-SYSTON and 44 per cent activated charcoal THIMET, were also pelleted on the seed with hydroxyethyl cellulose.

Test II

This test extended over a period of 30 days. Plants were counted two days after emergence of the alfalfa. At the time of this test, aphids were prevalent over the greenhouse, so recolonization of aphid populations on test pots was not necessary. Plants susceptible to aphid attack became infested upon emergence from the soil. Maximum infestation was 85 aphids per plant on the untreated plants. This infestation occurred 30 days post emergence.

In this test, one, one and one-half, and two pounds of actual DI-SYSTON and 0.88, 1.32, and 1.76 pounds of actual THIMET were pelleted on Oklahoma Common variety alfalfa seed with methyl cellulose. One and one-half pounds of actual DI-SYSTON and 0.88 and 1.32 pounds actual THIMET impregnated charcoal, pelleted with hydroxyethyl cellulose were also evaluated in this experiment.

Test IV

Plant and aphid counts were made over a period of 36 days. Plant emergence counts were taken seven days after emergence of alfalfa. One aphid per pot was introduced five days after emergence. After ten days post emergence, plants not infested were reinfested. The maximum infestation level was reached 32 days post emergence. At this time, aphids averaged 68.7 aphids per plant on untreated plants.

A resistant variety, Cody, was compared with systemic seed treatments of activated charcoal impregnated with 50 per cent DI-SYSTON and 44 per cent THIMET which were pelleted with hydroxyethyl cellulose and methyl cellulose. Both pelleting agents were used with one and one-half, two, and two and one-half pounds of actual DI-SYSTON and 1.32, 1.76, and 2.20 pounds of actual THIMET per 100 pounds of Buffalo variety alfalfa seed.

Test III

High Density Population Study

Four pots of Cody and four pots each of Buffalo variety alfalfa treated with two and with two and one-half pounds of actual DI-SYSTON per 100 pounds of seed on charcoal and pelleted with hydroxyethyl cellulose were used in this test. Approximately 20 to 30 seeds were planted in six-inch flower pots. Upon emergence, plants were thinned to one plant per pot.

Plants, two weeks after emergence, were inoculated with 100 aphids per plant. After introduction of the aphids, glass tubes were placed over the plants to prevent escape of aphids from test plants. These glass tubes, two inches in diameter, were sterilized in a sodium dichromate solution and rinsed in tap water. Strips of nylon cloth were placed over one end of the glass tubes and held in place by rubber bands.

Plants were observed daily for a period of 16 days. Daily damage observations were recorded. Other data taken include death of plants and length of time plants remained infested.

Results:

Although per cent emergence was very low in Tests I and II, seed treatment with systemic insecticides showed very little, if any, additional adverse effect upon seedling emergence of alfalfa plants (tables 21, 22, and 23). The seed contained some weevil damage when it was sowed. This probably accounts for low emergence from both treated and untreated seeds.

Although some treatments were inadequate as aphicides, all treated plants in Test I (table 24) showed less damage than the untreated plants. When pictures were taken (41 days post emergence), approximately one-half of the check plants were dead. Those still living at that time were badly damaged (figure 1). Plants still living in the check pots were badly wilted, with moderate to heavy chlorosis in the upper leaves

Table 21. Per cent seedling emergence from Oklahoma Common alfalfa seed treated with two systemic insecticides without pelleting material. Stillwater, Oklahoma. 1959.

	Per Cent Emergence			
	Pounds Actual per 100 Pounds of Seed			
	DI-SYSTON		THIMET	
Untreated	1.00	2.00	0.88	1.76
62.0	42.0	47.5	59.5	59.5

Table 22. Per cent emergence from Oklahoma Common alfalfa seed treated with two systemic insecticides and pelleted with hydroxyethyl cellulose sticker. Stillwater, Oklahoma. 1959.

	Per Cent Emergence					
	Pounds Actual per 100 Pounds of Seed					
	DI-SYSTON			THIMET		
Untreated	1.00	1.50	2.00	0.88	1.32	1.76
62.0	47.5		50.0	50.0		56.0
39.5		41.0			43.5	

Table 23. Per cent emergence from Oklahoma Common alfalfa seed treated with two systemic insecticides and pelleted with methyl cellulose sticker. Stillwater, Oklahoma. 1959.

	Per Cent Emergence					
	Pounds Actual per 100 Pounds of Seed					
	DI-SYSTON			THIMET		
Untreated	1.00	1.50	2.00	0.88	1.32	1.76
39.5	44.5	30.5	37.0	39.5	37.0	35.0

Table 24. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), obtained with two systemic insecticides applied as dry formulations. (Test I) Stillwater, Oklahoma. 1959.

Days After Emergence	Per Cent Control			
	Pounds Actual per 100 Pounds of Seed			
	DI-SYSTON		THIMET	
	1 Pound	2 Pounds	0.88 Pound	1.76 Pounds
7	100.0	100.0	100.0	100.0
11	79.1	83.8	61.7	75.6
14	48.5	91.1	21.7	79.1
18	59.2	93.5	46.5	79.4
22	52.9	85.5	13.3	59.4
28	10.8	68.4	0.0	28.8
32	10.0	2.7	0.0	0.0
36	8.9	55.6	0.0	0.0
41	0.0	0.0	0.0	0.0
46	0.0	10.0	7.0	0.0
49	0.0	0.0	0.0	0.0
54	0.0	32.3	0.0	0.0

Figure 1. Untreated Oklahoma Common alfalfa showing excessive damage, at 41 days post emergence, from attack of the spotted alfalfa aphid.

Figure 2. Comparison of damage, at 41 days post emergence, from untreated (check) plants of Oklahoma Common alfalfa with plants of the same variety grown from seed treated with two pounds of actual DI-SYSTON per 100 pounds of seed pelleted with hydroxyethyl cellulose.

Figure 3. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with one pound of actual DI-SYSTON per 100 pounds of seed as a dry activated charcoal formulation.

Figure 4. Protection afforded to Oklahoma Common alfalfa at 41 days post emergence, by seed treatment with 0.88 pound of actual THIMET per 100 pounds of seed as a dry activated charcoal formulation.

Figure 5. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with two pounds of actual DI-SYSTON per 100 pounds of seed as a dry activated charcoal formulation.

Figure 6. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with 1.76 pounds of actual THIMET per 100 pounds of seed as a dry activated charcoal formulation.

Figure 7. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with one pound of actual DI-SYSTON per 100 pounds of seed pelleted with hydroxyethyl cellulose.

Figure 8. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with 0.88 pound of actual THIMET per 100 pounds of seed pelleted with hydroxyethyl cellulose.

Figure 9. Protection afforded to Oklahoma Common alfalfa at 41 days post emergence, by seed treatment with two pounds of actual DI-SYSTON per 100 pounds of seed pelleted with hydroxyethyl cellulose.

Figure 10. Protection afforded to Oklahoma Common alfalfa, at 41 days post emergence, by seed treatment with 1.76 pounds of actual THIMET per 100 pounds of seed pelleted with hydroxyethyl cellulose.

and necrotic lower leaves. Aphids lined the stems and underside of the leaves, although they cannot be seen in the picture. Even if aphid populations were to disappear at this point, most of the plants would never recover from this severe damage.

It can be seen in table 24 that neither one or two pounds of DI-SYSTON nor 0.88 or 1.32 pounds of THIMET on charcoal alone gave adequate control. These treatments were effective for only about one week and failed thereafter.

Of the unpelleted treatments, 0.88 pound of actual THIMET per 100 pounds of seed was least effective and two pounds of actual DI-SYSTON per 100 pounds of seed was most effective. One pound DI-SYSTON and 1.76 pounds THIMET treatments were closely comparable in effectiveness. THIMET at 1.76 pounds per hundred was slightly more effective at first, but DI-SYSTON at one pound per hundred showed insecticidal properties for a longer period, so that the total protection of alfalfa plants was similar for the two treatments.

All alfalfa treated with systemic materials on activated charcoal showed severe damage at 41 days (figures 3, 4, 5, and 6). Very little difference in visible damage can be seen in plants treated with one pound of actual DI-SYSTON (figure 3), 0.88 pound of actual THIMET (figure 4), or 1.76 pounds of actual THIMET (figure 6). Plants grown from seed treated with two pounds of actual DI-SYSTON on activated charcoal was least damaged by aphids of the unpelleted treatments (figure 5). This treatment, however, did not afford adequate protection for seedling alfalfa plants. It can be seen, then, that seeds treated with systemic insecticides on activated charcoal (without sticker) is not an effective control agent against the spotted alfalfa aphid, regardless of the insecticide or the rate of insecticide used.

Much better control resulted from the use of hydroxyethyl cellulose as an adhesive agent to stick systemic insecticides on the seed coat. Both systemic materials were more effective when the sticker was added although THIMET did not prove to be an effective aphicide under either condition.

Two pounds of actual DI-SYSTON, pelleted on to the seed with hydroxyethyl cellulose, rendered the best control for the period. This material effectively protected alfalfa plants for 36 days. Figure 9 shows this treatment at 41 days post emergence. No chlorosis or wilting could be seen in plants at that time. Figure 2 contrasts untreated plants with those treated with two pounds of DI-SYSTON, pelleted with hydroxyethyl cellulose.

Insecticidal activity was completely gone from the two-pound DI-SYSTON and hydroxyethyl cellulose treatment in 54 days. Effectiveness of this material dropped from 50.1 per cent control at 49 days to 0.00 per cent control at 54 days.

One pound of DI-SYSTON, pelleted with hydroxyethyl cellulose was effective for 22 days (table 25). The plants so treated showed only light to moderate damage after 41 days (figure 7). Though definitely inferior to the two-pound rate, this treatment gave much protection to the alfalfa plants, as compared to the two rates of THIMET, pelleted with the same sticking agent.

One and seventy-six hundredths pounds of THIMET per hundred pounds of seed, using hydroxyethyl cellulose as a sticker, was more effective than 0.88 pound of THIMET per hundred. Both rates using the sticker

Table 25. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), obtained with two systemic insecticides pelleted on seed with hydroxyethyl cellulose sticker. (Test I) Stillwater, Oklahoma. 1959.

	Per Cent Control			
Days	Pounds Actual per 100 Pounds of Seed			
After	DI-SYSTON		THIMET	
Emergence	1 Pound	2 Pounds	0.88 Pound	1.76 Pounds
7	100.0	100.0	100.0	100.0
11	88.4	88.4	86.1	86.1
14	99.9	99.7	71.7	86.6
18	99.8	100.0	69.6	86.9
22	89.6	99.6	61.3	68.3
28	80.2	92.8	41.3	59.7
32	46.3	91.4	0.0	18.1
36	63.2	89.0	0.0	31.7
41	15.2	72.1	0.0	11.7
46	23.2	63.0	18.0	31.0
49	14.3	50.1	0.2	27.7
54	0.0	0.0	0.0	0.0

were more effective than either rate of the same material without a sticker. Two pounds of DI-SYSTON applied to the seed on activated charcoal alone, however, was slightly more effective than either rate of THIMET with a sticker added. Much chlorosis and wilting of leaves and a general unthriftiness of the plants treated with 0.88 and 1.76 pounds of THIMET plus hydroxyethyl cellulose can be seen in figures 8 and 10.

Test II was conducted to determine the effectiveness of one and one-half pounds of DI-SYSTON and 1.32 pounds of THIMET per 100 pounds of seed, pelleted with hydroxyethyl cellulose. One, one and one-half, and two pounds of DI-SYSTON and 0.88, 1.32, and 1.76 pounds of THIMET were also pelleted with methyl cellulose to be compared to the control from the same rates of THIMET and DI-SYSTON in Test I. Results from this test were very disappointing. No treatment was effective for more than two weeks (tables 26 and 27). This test does indicate, however, that hydroxyethyl cellulose is a slightly more efficient sticking agent than methyl cellulose.

At the time Test II was conducted, the aphid population in the greenhouse was very high. Because of the high aphid population and lack of effectiveness from systemic seed treatments in Test II, it was logical to assume that treatment of alfalfa seed with systemic insecticides was effective in protecting the plants when aphid populations were at ordinary density but was not effective when population densities were extremely high. If this were true, systemic seed treatment would not protect small seedling alfalfa from aphids migrating in large numbers out of a nearby heavily infested, older alfalfa field. Test III was established to determine if high density

Table 26. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), obtained with two systemic insecticides pelleted with hydroxyethyl cellulose sticker. (Test II) Stillwater, Oklahoma. 1959.

Days After Emergence	Per Cent Control: Pounds Actual per 100 Pounds of Seed — DI-SYSTON 1.50 Pounds	THIMET 1.32 Pounds
9	73.0	93.0
14	0.0	94.8
18	0.0	76.2
21	0.0	62.8
25	0.0	0.0
28	0.0	0.0
30	0.0	0.0

Table 27. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), obtained with two systemic insecticides pelleted with methyl cellulose sticker. (Test II). Stillwater, Oklahoma. 1959.

Days After Emergence	Per Cent Control: Pounds Actual per 100 Pounds of Seed — DI-SYSTON 1.00 lb.	DI-SYSTON 1.50 lbs.	DI-SYSTON 2.00 lbs.	THIMET 0.88 lb.	THIMET 1.32 lbs.	THIMET 1.76 lbs.
9	84.7	72.5	99.8	97.0	98.1	64.1
14	68.9	90.8	94.3	0.0	0.0	0.0
18	0.0	14.7	0.0	0.0	0.0	0.0
21	0.0	48.7	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0

aphid populations would prove as detrimental to seed treated plants as to a resistant variety. Although only one age plant (two weeks post emergence) was studied, it answers some questions raised by the results from Test II.

No plant, treated with systemic materials pelleted on the seed with hydroxyethyl cellulose, died from the 100 aphids per plant infestation. Two of the four plants of resistant variety, Cody, were killed by the "overflow" aphid population, one plant at 13 days and the other at 16 days after introduction.

At 24 hours after introduction of the aphids, all plants were still infested. However at two days, none of the plants treated with two and one-half pounds per hundred of actual DI-SYSTON were infested. One replicate of the two pounds actual DI-SYSTON per hundred was infested with two live aphids at two days, but was not infested at all at the end of three days. Cody supported a light aphid infestation on all plants until seven days. At seven days after introduction of the aphid population, one of the four Cody replicates did not show an aphid population. At the thirteenth day after introduction, one plant was dead and two of the three still alive were infested. Three days later (16 days), none of the remaining Cody plants were infested. At this time, two of the four plants were dead, and the other two were not infested.

Aphid damage developed much faster in the seed treated plants than in the resistant variety (table 28). This suggests the possibility that repeated introductions of high density aphid populations might cause severe damage or death of the plants. This would account for the poor results shown in tables 26 and 27. In spite of obtaining systemic insecticide from the plants the aphids injected toxins. Therefore, although one infestation of a high density population did not kill the plants, additional reinfestations would each contribute damage which would eventually result in plant death.

At one day after introduction of the aphids, seed treated plants showed slight wilting and occasional yellow-veining of the leaves. Cody showed only a slight wilting of a few leaves for the period. At two days after introduction, systemic seed treated plants showed light to moderate yellow-veining of the leaves; however Cody still displayed a slight leaf-wilt as the only visible damage. Resistance in Cody, then, is probably due largely to its higher tolerance of aphid feeding.

Buffalo variety alfalfa plants from seed treated with systemic insecticides showed heaviest aphid damage at two and three days. The visible damage decreased slowly thereafter. No damage could be seen in the seed treated plants after 13 days. It may be noted that no significant difference in the amount of visible damage can be seen between plants treated with two or with two and one-half pounds of DI-SYSTON per 100 pounds of seed. Cody displayed only slight damage at three days, but damage increased until the seventh day. Damage was most severe from the seventh to the ninth day, after which plants either died or lost infestations. After 16 days, the two remaining Cody plants displayed only slight yellow-veining in the leaves.

All systemic insecticides at all rates rendered adequate control for 32 to 36 days in Test IV (tables 29, 30, 31, and 32). DI-SYSTON at two and one-half pounds actual per 100 pounds of seed, pelleted with hydroxyethyl cellulose was the most effective treatment used. DI-SYSTON was slightly more effective than THIMET in this test when both were used

Table 28. Damage caused by high density populations of the spotted alfalfa aphid _Therioaphis maculata_ (Buckton), to Cody alfalfa and to Buffalo alfalfa the seed of which was treated with a systemic insecticide and pelleted with hydroxyethyl cellulose. (Test III) Stillwater, Oklahoma. 1959.

	Damage Rating		
		DI-SYSTON Treated	
	Cody	Pounds Actual per 100 Pounds of Seed	
Days	Variety	2 Pounds	$2\frac{1}{2}$ Pounds
1	*	**	**
2	*	***	***
3	*	***	***
4	**	**	**
5	***	**	**
6	***	**	**
7	****	**	**
8	****	*	*
9	****	*	*
13	***	0	0
16	**	0	0

0 No visible damage
* Very light chlorosis of lower leaves and/or slight wilting of top leaves
** Light chlorosis of lower and top leaves (yellow-veining) and light wilting of leaves
*** Moderate chlorosis of leaves (general yellowing) and moderate degree of wilting; plant stunted; little growth
**** Heavy chlorosis of leaves (yellow) and heavy wilting of plant (stems and leaves); no growth

Table 29. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), obtained with DI-SYSTON pelleted on seed with hydroxyethyl cellulose sticker. (Test IV) Stillwater, Oklahoma. 1959.

Days After Emergence	Cody Variety	Per Cent Control DI-SYSTON Treated Pounds Actual per 100 Pounds of Seed 1.50 Lbs.	2.00 Lbs.	2.50 Lbs.
7	0.0	100.0	100.0	100.0
10	24.3	100.0	100.0	100.0
14	62.9	100.0	100.0	100.0
18	77.1	100.0	99.2	100.0
22	73.9	100.0	100.0	100.0
25	71.1	100.0	100.0	100.0
29	65.9	98.5	97.8	99.8
32	80.2	98.8	98.2	99.3
36	61.9	90.7	99.6	99.2

Table 30. Control of the spotted alfalfa aphid, Therioaphis maculata (Buckton), obtained with DI-SYSTON pelleted on the seed with methyl cellulose sticker. (Test IV) Stillwater, Oklahoma. 1959.

Days After Emergence	Per Cent Control		
	DI-SYSTON Treated		
	Pounds Actual per 100 Pounds of Seed		
	1.50 Lbs.	2.00 Lbs.	2.50 Lbs.
7	100.0	100.0	100.0
10	100.0	100.0	100.0
14	100.0	100.0	100.0
18	100.0	100.0	100.0
22	100.0	100.0	100.0
25	100.0	99.6	100.0
29	99.5	97.3	99.9
32	98.7	98.0	99.8
36	97.5	96.2	97.5

Table 31. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), obtained with THIMET pelleted on the seed with hydroxyethyl cellulose sticker. (Test IV). Stillwater, Oklahoma. 1959.

Days After Emergence	Per Cent Control: THIMET Treated, Pounds Actual per 100 Pounds of Seed		
	1.32 Lbs.	1.76 Lbs.	2.20 Lbs.
7	100.0	60.0	100.0
10	100.0	100.0	100.0
14	92.7	100.0	100.0
18	98.1	98.3	100.0
22	97.9	99.6	100.0
25	99.4	99.3	100.0
29	96.3	99.3	99.9
32	91.0	87.1	99.7
36	48.3	54.2	93.7

Table 32. Control of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), obtained with THIMET pelleted on the seed with methyl cellulose sticker. (Test IV) Stillwater, Oklahoma. 1959.

Per Cent Control			
Days After Emergence	THIMET Treated		
	Pounds Actual per 100 Pounds of Seed		
	1.32 Lbs.	1.76 Lbs.	2.20 Lbs.
7	100.0	100.0	100.0
10	100.0	100.0	100.0
14	100.0	100.0	99.2
18	99.8	100.0	99.2
22	99.4	100.0	99.5
25	99.4	100.0	99.7
29	92.0	99.0	99.5
32	93.6	95.7	98.5
36	75.0	57.6	89.0

at similar rates. Hydroxyethyl cellulose appears to be a slightly more effective sticking agent than methyl cellulose. Effectiveness of either chemical increased with an increase in rate from one and one-half to two and one-half pounds of actual material per 100 pounds of seed. This increase in dosage would not be economically feasible unless the higher rate would offer a significantly longer protection period.

A typical check pot from Test IV can be seen in figure 11. Many of the untreated plants were dead at 40 days. Those still alive were stunted, wilted, and showed moderate to heavy chlorosis. Figures 13, 14, 15 and 16 show plants treated with THIMET and DI-SYSTON pelleted with methyl cellulose which were not shown in pictures from Test I. DI-SYSTON at two and one-half pounds (figure 15) and THIMET at 2.20 pounds (figure 16) show no damage. DI-SYSTON at one and one-half pounds (figure 13) and THIMET at 1.32 pounds (figure 14) show only slight damage.

Cody was not at all effective as a resistant variety at seven days (table 29). However, the effectiveness of Cody increased with an increase in plant age, up to the 32-day count. Moderate chlorosis can be seen on the Cody variety in figure 12. This treatment showed much more damage than any other treatment under study in Test IV.

Systemic seed treated plants are most protected immediately after emergence but this decreases as the plant grows older, whereas Cody was not protected immediately after emergence but gained protection with an increase in age of the plants. These facts suggest the possibility of an immediate and longer lasting control by treating Cody alfalfa seed with DI-SYSTON, pelleted with hydroxyethyl cellulose or methyl cellulose.

Figure 11. Untreated Buffalo alfalfa, at 40 days post emergence, showing excessive damage and dead plants caused by attacks of the spotted alfalfa aphid.

Figure 12. Effects of a spotted alfalfa aphid infestation on the resistant alfalfa variety Cody, at 40 days after emergence.

Figure 13. Protection afforded to Buffalo alfalfa, at 40 days post emergence, by seed treatment with 1.50 pounds of actual DI-SYSTON per 100 pounds of seed pelleted with methyl cellulose.

Figure 14. Protection afforded to Buffalo alfalfa, at 40 days post emergence, by seed treatment with 1.32 pounds of actual THIMET per 100 pounds of seed pelleted with methyl cellulose.

Figure 15. Protection afforded to Buffalo alfalfa, at 40 days post emergence, by seed treatment with 2.50 pounds of actual DI-SYSTON per 100 pounds of seed pelleted with methyl cellulose.

Figure 16. Protection afforded to Buffalo alfalfa, at 40 days post emergence, by seed treatment with 2.20 pounds of actual THIMET per 100 pounds of seed pelleted with methyl cellulose.

Summary:

Systemic seed treatment had no adverse effect on alfalfa emergence. No rate of THIMET or DI-SYSTON afforded adequate control of the spotted alfalfa aphid when applied to the seed as activated charcoal alone. However, one and one-half, two, and two and one-half pounds of actual DI-SYSTON or 1.32, 1.76, and 2.20 pounds of THIMET per 100 pounds of seed when pelleted on the seed with hydroxyethyl cellulose or methyl cellulose rendered good control for 32 to 36 days. DI-SYSTON was more effective than THIMET at similar rates. Hydroxyethyl cellulose was a more efficient pelleting agent than methyl cellulose. In the 1.32 to two and one-half pounds per hundred pounds range, higher rates of insecticides are slightly more effective than lower rates; dosages below 1.32 pounds per hundred were much less effective.

Systemic seed treated plants, two weeks after emergence, are able to withstand high density aphid infestations, suffering only light to moderate chlorosis of the leaves. These plants were not infested for more than three days after introduction of the aphids. Cody variety alfalfa, however, was heavily damaged by high density aphid populations. During the 15 days after aphid introduction, half of the Cody plants were killed. Cody showed damage much slower than did the Buffalo variety alfalfa which was treated with systemic materials. This suggests that a major part of Cody's resistance is due to its high tolerance of aphid populations; it also suggests that repeated reinfestations of high density aphid populations might cause severe damage or death of plants of the Buffalo variety.

Systemic seed treated plants were effectively protected immediately after emergence of the plants but this protection decreased with increase in age of the plants. The resistant variety, Cody, was not protected immediately after emergence but became increasingly so later. Systemic seed treatment of Cody variety alfalfa with one and one-half, two, or two and one-half pounds per 100 pounds of seed, pelleted with hydroxyethyl cellulose, might be employed to give immediate and lasting control of the spotted alfalfa aphid.

SUMMARY AND CONCLUSIONS

In general, control procedures should be administered to Buffalo variety alfalfa when: (1) three aphids per plant are found at emergence, (2) three aphids per plant found at one week, (3) 10 aphids per plant found at two weeks, (4) 10 aphids per plant at three weeks, or (5) over 10 aphids per plant found at four weeks. Lighter infestations than these would warrant insecticide application, however, if plants had been damaged badly by prior aphid feeding or some other condition that might have caused an unthrifty condition in the plant.

The resistance qualities of Cody variety alfalfa increase slightly with increase in plant age. Two resistance qualities of this variety were noted. One of these was its repellency of aphid populations. The other, a more effective quality, was the ability to tolerate feeding of the spotted alfalfa aphid.

Reproduction of this insect was lowest at a mean temperature of 25 degrees F. and increased with an increase in temperature to 75 degrees F. At 85 degrees, however, reproduction decreased to a point slightly below the 65-degree level. Reproduction reached its peak at 75 degrees. Mortality was lowest at 55 degrees F. and highest at 85 degrees F.

Aphid populations reached their maximum at 65 degrees F. and a point of extinction was reached at 25 degrees F. Activity and aphid feeding increased with an increase in temperature, from practically no activity and feeding at 25 degrees F. to an active and vigorously feeding population at temperatures of 45 degrees F. and above.

Because of a declining population, lack of normal aphid feeding habits, and low mortality from insecticides at 25 degrees F., chemical control does not seem feasible at this temperature level, even at 35 degrees F. it is questionable. Control should be encouraged, however, when populations reach excessively damaging levels at temperatures at or above 45 degrees F.

A number of insecticides provided good low temperature control of the spotted alfalfa aphid, although most did not show adequate mortality until seven to ten days. After treatment at 30 to 40 degrees F., methyl parathion was the only insecticide that consistently delivered excellent mortality. Ethyl parathion also gave adequate control, especially at this low temperature when aphid reproduction is very low. At 40 to 50 degrees F., KORLAN and PERTHANE rendered excellent control and PHOSPHAMIDON gave good control. Insecticide control of the pest at 60 to 70 degrees F. was poor; however malathion delivered the best moderate-temperature results of the insecticides tested.

Malathion dissolved in soltrol rendered a higher and a faster mortality than malathion alone. This suggests the use of soltrol as a carrier for insecticides, rather than water, for cold weather chemical control agents.

Systemic seed treatment had no adverse effect on alfalfa emergence. No rate of THIMET or DI-SYSTON afforded adequate control of the spotted alfalfa aphid when applied to the seed as activated charcoal alone. However, one and one-half, two, and two and one-half pounds of actual

DI-SYSTON OR 1.32, 1.76, and 2.20 pounds of actual THIMET per 100 pounds of seed when pelleted on the seed with hydroxyethyl cellulose or methyl cellulose rendered good control for 32 to 36 days. DI-SYSTON was more effective than THIMET at similar rates. Hydroxyethyl cellulose was a more efficient pelleting agent than methyl cellulose. In the 1.32 to two and one-half pounds per 100 pounds range, higher rates of insecticides are slightly more effective than lower rates; dosages below 1.32 pounds per hundred were much less effective.

Systemic seed-treated plants, two weeks after emergence, are able to withstand high density aphid infestations, showing only light to moderate chlorosis of the leaves. These plants were not infested for more than three days after introduction of the aphids. Cody variety alfalfa, however, was heavily damaged by high density aphid populations. During the 15 days after aphid introduction half of the Cody plants were killed.

Systemic seed treated plants were effectively protected immediately after emergence of the plants but this decreased with increase in age of the plants. Cody, however, was not protected immediately after emergence but became increasingly so with age. Systemic seed treatment of Cody variety alfalfa with one and one-half, two, or two and one-half pounds per 100 pounds of seed, pelleted with hydroxyethyl cellulose, then, might be employed to give immediate and lasting control of the spotted alfalfa aphid.

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